



EPA Region 5 Records Ctr.



208894

Solutia Inc.

575 Maryville Centre Drive
St. Louis, Missouri 63141

P.O. Box 66760

St. Louis, Missouri 63166-6760

Tel/ 314-674-1000

April 19, 2004

Mr. Nabil Fayoumi
USEPA Region 5
55 West Jackson Blvd.
Chicago, IL 60604

Re: Sauget Area 1 EE/CA
DNAPL Characterization and Remediation Study
Work Plan, Field Sampling Plan, Quality
Assurance Project Plan and Health and Safety
Plan

Dear Mr. Fayoumi,

Enclosed are the Sauget Area 1 DNAPL Characterization and Remediation Study Work Plan, which includes the Field Sampling Plan and the Health and Safety Plan, and the Sauget Area 1 DNAPL Characterization and Remediation Study Quality Assurance Project Plan. The Agency's November 4, 2003 comments and the comments in the December 23, 2003 Conditional Approval are incorporated in the Work Plan and Field Sampling Plan.

The QAPP and HASP are based on the Agency-approved QAPP and HASP for the Sauget Area 1 RI/FS Support Sampling Plan. Both documents were updated to reflect the procedures, protocols and methods associated with a DNAPL investigation and are currently being used for the W.G. Krummrich RCRA AOC DNAPL Characterization and Site Corrective Measures Study Work Plan.

Sincerely

Steven D. Smith

cc:	Ken Bardo	USEPA Region 5 - RCRA
	Sandra Bron	IEPA
	Glen Kurowski	Monsanto
	Richard Williams	Solutia
	Bruce Yare	Solutia
	Joe Grana	Cerro
	Steve Schmidt	ExxonMobil

Work Plan for DNAPL Characterization and Remediation Study

**Sauget Area 1 Sites
Sauget, Illinois**

April 1, 2004



Groundwater Services, Inc.
2211 Norfolk, Suite 1000, Houston, Texas 77098-4054
(713)522-6300

WORKPLAN FOR DNAPL CHARACTERIZATION AND REMEDIATION STUDY Sauget Area 1 Sites, Sauget, Illinois

1.0 INTRODUCTION

As requested by Solutia, Groundwater Services, Inc. (GSI), has prepared this workplan for a characterization and remediation study of dense non-aqueous phase liquids (DNAPLs) in the subsurface underlying the Sauget Area 1 Sites in Sauget, Illinois. The study focuses on Sauget Area 1 Sites G, H, I, and L.

EPA Letter

This workplan addresses the issues presented in the U.S. letter to Solutia dated January 9, 2003, where a DNAPL study was requested with these focus areas:

The characterization and distribution of DNAPL within the middle and deep hydrogeologic units, the assessment of DNAPL migration under current and future site conditions, and the risk of uncontrolled DNAPL mobilization.

The extent and properties of DNAPL (e.g., density, viscosity, and interfacial tension); as well as the timing of the DNAPL release; topography, property, and heterogeneity of geologic units on which the DNAPL may accumulate; the existence of ongoing DNAPL releases; and transport characteristics of the bedrock.

The evaluation of the DNAPL remedial options and the evaluation of the benefits and costs associated with source removal technologies (e.g., thermal technologies such as steam injection and chemically-enhanced extraction such as the use of surfactants or co-solvents).

This workplan incorporates comments provided by Dr. Steven Acree of U.S. EPA and comments by Laramide Environmental, an EPA contractor, who reviewed previous versions of this workplan.

Sites of Interest for DNAPL Investigation at Sauget Area 1

Sites G, H, and I were previously used for disposal of industrial, commercial, and municipal waste materials. Historical information indicates that liquid waste disposal was conducted at Sites G, H, and I. Site L was used as a tank truck washout lagoon, with an overflow to Dead Creek. These four sites were selected as the primary areas of interest for the DNAPL investigation of Sauget Area 1.

Site N was a former borrow pit that was used for disposal of construction rubble. DNAPL investigation is not proposed for Site N because DNAPL is not expected at this site given the nature of historical operations.

2.0 CONCEPTUAL SITE MODEL

DNAPL Distribution - An objective evaluation of existing data indicates that:

- Pooled DNAPL is or may be present in Sites G, H, I and/or L;
- DNAPL is or may be present as small, discreet blobs and/or ganglia in the unsaturated zone;
- DNAPL is or may be present as small, discreet blobs and/or ganglia in the saturated zone;
- Dissolved DNAPL is or may be present in the aquifer beneath and downgradient of Sites G, H, I and/or L; and
- Pooled DNAPL is or may be present at the alluvial aquifer/bedrock interface beneath or downslope of Sites G, H, I and/or L.

Sites G, H, I and L cover an area of 27.55 acres broken down as follows: Site G - 4.33 Acres, Site H - 5.22 Acres, Site I - 16.88 Acres and Site L - 1.12 Acres. With depth to bedrock of somewhere between 100 and 120 feet at these former disposal areas, the potential volume of DNAPL-containing waste and soil is unknown but could be as much as approximately 4.4 million cubic yards (i.e., 1.0 million cubic yards of waste and 3.4 million cubic yards of underlying aquifer materials). Figure 4 shows the known or suspected vertical distribution of DNAPL within and beneath the Sauget Area 1 source areas.

Human Health and Environmental Protection - Groundwater usage in the Villages of Sauget and Cahokia is prohibited by ordinance. There is no evidence that anyone in Sauget or Cahokia receives drinking water from the groundwater. In fact, there is a public source of drinking water from an intake of the Mississippi River far downstream of the impacted sites. Consequently, there is no immediate threat to public health due to the presence of DNAPL associated with Sites G, H, I, and L. There is a potential for harm if workers were exposed to DNAPL in the course of intrusive work during construction activities. However, this potential exposure can be controlled by implementing institutional controls and local ordinances prescribing the circumstances under which intrusive activities can be performed.

The only other potential for impact from the presence of DNAPL is the dissolution of the DNAPL from the aquifer matrix beneath and adjacent to these disposal sites. Plume migration projections performed as part of the Sauget Area 1 Engineering Evaluation/Cost Analysis and Remedial Investigation/Feasibility Study (i.e., the EE/CA and RI/FS Report) indicate that mobile constituents from Site I could reach the Mississippi River, which is 5500 feet from Site I. Results from particle-track modeling (see Figure 1) indicate that, with the exception of groundwater from the very northern portion of Site I, impacted groundwater migrating from Sites G, H, I and L, Dead Creek Segment B north of Site M, Sauget Area 2, and other Sauget facilities will be captured by the Sauget Area 2 Interim Groundwater Remedy, which is currently being installed. When completed, the Sauget Area 2 Interim Groundwater Remedy will abate surface water impacts resulting from groundwater discharge to surface water downgradient of Sauget Area 2 Sites O, Q (Dog Leg), R and S; Sauget Area 1 Sites G, H, I and L; Dead Creek Segment B north of Site M; the W.G. Krummrich plant and other industries in the Sauget area.

ARARs - Dissolution of DNAPL trapped in the aquifer matrix currently exceeds Illinois Class I Groundwater Standards and will continue to do so in the future, .i.e. ARARs are now and will continue to be exceeded. Time to clean estimates made as part of the Sauget Area 1 EE/CA and RI/FS Report (see Section 3.0 of this Work Plan, "Previous Source Evaluation Study") indicate that Illinois Class I groundwater standards would be achieved in 488 years with no action and in 441 years with aggressive pumping at a flow rate of 1500 gpm. Planning-level calculations by GSI suggest that a DNAPL mass removal of 99.97% could be needed to achieve ARARs within 5 years and a mass removal of 99.96% could be needed to achieve ARARs in 30 years. Key assumptions for these calculations are i) an assumed starting source mass of 410,000 kg of DNAPL; and ii) changes in COC concentrations in groundwater are directly proportional to changes in DNAPL mass in the aquifer matrix.

Basis for Investigation - Based on this Conceptual Site Model (Figure 4), the DNAPL Characterization and Remediation Study is focused on collecting the information needed for i) estimation of the volume of DNAPL-affected material; ii) assessment of the ability to remove DNAPL from the aquifer matrix by treatment; iii) estimation of the removal efficiencies of various treatment technologies; and iv) determination of the presence of pooled DNAPL. These data will be used to determine if aggressive source treatment will make any meaningful difference in the time required to achieve ARARs and, if so, the cost of such treatment.

3.0 BACKGROUND INFORMATION UTILIZED IN WORKPLAN DEVELOPMENT

Available Data Regarding Occurrence of DNAPL at Sauget Area 1

The Sauget Area 1 EE/CA and RI/FS Report, issued in June 2001, discusses the potential for DNAPL occurrence at Sauget Area 1 based on analysis of several indicators, including: i) increasing COC concentrations with depth; ii) presence of COCs deep in the alluvial aquifer; and iii) presence of some COCs at concentrations in excess of 1% of the pure-phase solubility. It is expected that much of the DNAPL mass at Sauget Area 1 is trapped by capillary forces within the alluvial aquifer pore space as small, discrete blobs and ganglia. However, some free-phase DNAPL may have migrated to the bedrock surface, where it may be present in free-phase pools.

As discussed in the EE/CA and RI/FS Report, three monitoring wells, BR-G, BR-H, and BR-I, were installed to evaluate conditions at the alluvial aquifer/bedrock interface at Sites G, H, and I, respectively. As discussed in Section 5.2.3.6 of the EE/CA and RI/FS Report, free-phase DNAPL was noted during the sampling of monitoring well BR-I. As discussed in Section 5.2.3.3, the potential presence of free-phase DNAPL was noted during the sampling of well BR-G, but not at well BR-H.

Numerous monitoring wells and piezometers at Sauget Area 1 are screened in the shallow and middle hydrogeologic units of the alluvial aquifer, but the extent of free-phase DNAPL in these wells and piezometers requires further evaluation. A report prepared by the U.S. Army Corps of

Engineers (USACE) included a table that suggested the presence of DNAPL in 43 wells and piezometers at Sauget Area 1 (see Table 4-0c in Attachment 1 of this workplan). Table 4-0c was prepared by the USACE based on review of field notes recorded during measurement of well and piezometer water levels in 1999-2000.

GSI used the information from Table 4-0c to prepare a map of inferred DNAPL distribution at Sauget Area 1 (see Figure 2). A separate map (see Figure 3) was prepared to show the estimated extent of DNAPL based on concentrations of total VOCs in groundwater as reported on Figure 4-18 of the EE/CA and RI/FS report. On Figure 3, DNAPL is inferred to be present at locations where the concentration of total VOCs in groundwater exceeds 1% of the pure phase solubility of chlorobenzene, a VOC which is detected at elevated levels at Sauget Area 1.

Task 2 of this workplan includes a survey to measure free-phase DNAPL thickness at all existing monitoring wells and piezometers located at Sauget Area 1. With measurements from approximately 56 wells and piezometers, the results of this survey will provide clarification regarding the thickness and extent of free-phase DNAPL at Sauget Area 1.

Previous Source Evaluation Study

Solutia investigated source mechanisms at Sauget Area 1 in a report issued by GSI on May 21, 2001. A copy of the report is included as Attachment 2 with this workplan. The report, which was presented as Appendix C in the Sauget Area 1 EE/CA and RI/FS Report, focused on Site I and addressed two issues:

- 1) *What is the dominant source mechanism at the site?*
- 2) *What is the effect of an intensive pump-and-treat system on the lifetime of the source?*

The report concluded that *DNAPL dissolution* is a major source mechanism at Site I based on several indicators, most importantly: 1) dissolved constituent concentrations increase with depth; 2) site constituents extend from the water table to the bottom of the water-bearing interval; and 3) three constituents are found at concentrations that suggest the possible presence of DNAPL. Some leaching of unsaturated waste/soil materials may also be occurring, as some constituents did not show increasing concentrations with depth. Overall, however, DNAPL dissolution appears to be the dominant source mechanism at Site I.

If DNAPL dissolution is the dominant source mechanism at Site I, it is likely that the DNAPL in the aquifer matrix is present as thin vertical fingers and small horizontal pools throughout the entire vertical extent of the water-bearing unit.

A planning level source lifetime calculation was done to estimate the relative performance of various pumping schemes on removing DNAPL from the aquifer matrix. This analysis, while not providing high-confidence estimates of the absolute time to cleanup, indicates that with an assumed mass of 410,000 kg of VOCs and SVOCs in the saturated zone below Site I, intensive groundwater pumping over a 10 to 30 year period does not appear to have an appreciable effect on overall source lifetime (i.e., it will provide only a $\leq 10\%$ reduction).

Limitations on Feasibility of Large-Scale Source Remediation at Sauget Area 1

Large scale-remediation of sites in Sauget Area 1 would be costly. One of the best examples of large-scale source treatment is the Visalia site in Visalia, California. At this site, steam injection was used to treat a 4-acre area with an 80-ft thick treatment zone. The total remediation cost for this site was \$22 million, giving unit costs of \$5.5 million per acre and \$57/yd³. If these unit costs were applied to Sites G, H, I, and L (total area of 27.55 acres), the total costs would be within the \$220-\$440 million range discussed in Section 2.0, Conceptual Site Model. Other intensive source treatment alternatives (e.g., surfactants, biodegradation) have unit costs that are in the same general range as thermal treatment.

Typical removal efficiencies for these types of technologies range from 50% to 90% of the contaminant mass in the source. Because no technologies have the ability to completely restore DNAPL source zones, some source mass will be left behind and serve as a long-term source of site constituents to groundwater. Long-term care (i.e., containment of groundwater plumes) would likely be required at these sites even if intensive source removal was performed.

4.0 WORKPLAN TASKS

Task 1: Project Startup, Review of Existing Data, and Contractor Scheduling

Prior to the start of the field program, GSI will review the existing Sauget Area 1 Health and Safety Plan to confirm that it addresses all anticipated field activities that are included in this work plan, including drilling and sampling in Level B personal protective equipment. Amendments to the Health and Safety Plan, if any, will be completed and reviewed by Solutia *prior to the start of field activities*.

Previous site reports, which include bedrock core photographs and analysis of petrographic thin sections, will be used in the evaluation of bedrock transport characteristics for this study. Historical site information from previous reports will be used to evaluate possible timing of DNAPL releases. As discussed above, groundwater concentration data and measurements listed on Table 4-0c from the USACE report have been reviewed as indicators of possible DNAPL presence.

This task will also include scheduling and coordination with the geophysical contractor, drilling contractor, and laboratories that will be involved in the implementation of this work plan.

Task 2: DNAPL and LNAPL Survey and Recovery Tests at Existing Wells

A survey will be conducted to check for the possible presence of free-phase LNAPL and DNAPL at 56 monitoring wells and piezometers located at and near the Area 1 sites.

Monitoring Wells and Piezometers to be Included in Initial DNAPL Survey	
Location	Well or Piezometer I.D.
Site G	BR-G, EE-05, EEG-101, EEG-102, EEG-104, EEG-106, EEG-107, EEG-112, ST-G-S, ST-G-M, and ST-G-D.
Site H	BR-H, EE-01, EE-03, EE-04, EEG-110, ST-H-S, ST-H-M, and ST-H-D.
Site I	BR-I, EE-20, P1-A-S, P1-A-M, P1-A-D, P1-B-S, P1-B-M, P1-B-D, P1-C-S, P1-C-M, P1-C-D, ST-H-S, ST-H-M, and ST-H-D.
Site L	EEG-108, EEG-109.
Various Area 1 Locations	P2-A-S, P2-A-M, P2-A-D, P2-B-S, P2-B-M, P2-B-D, P2-C-S, P2-C-M, P2-C-D, P3-A-S, P3-A-M, P3-A-D, P3-B-S, P3-B-M, P3-B-D, P3-C-S, P3-C-M, P3-C-D, ST-N-S, ST-N-M, and ST-N-D.
Notes:	
1) The following wells and piezometers reportedly no longer exist and are therefore not included in the DNAPL and LNAPL survey: EE-12, EE-13, EE-15, EEG-105, ST-L-S, ST-L-M, and ST-L-D. 2) The following wells and piezometers reportedly can no longer be sampled and are therefore not included in the DNAPL and LNAPL survey: EE-02, EE-14, EEG-103, and EEG-111.	

Table 1 lists the total depth and the hydrogeologic interval that is screened at each existing well and piezometer. At each well or piezometer, the survey will include measurement of the depth to water and a check for the presence and thickness of LNAPL or DNAPL using an electronic interface probe. A disposable Teflon bailer will be lowered to the water level in each well to check for the possible presence of accumulated LNAPL. A visual check for DNAPL will be performed by lowering a weighted cotton string to the bottom of the well, then retrieving the string to inspect for evidence of staining. Finally a disposable Teflon bailer will be lowered to the bottom of each well to check for the presence of accumulated DNAPL. New string, bailer, and bailer cord will be used for each well, and soiled string, bailers, and cord generated during the survey will be placed in a designated container for management by Solutia.

At each well or piezometer where free phase NAPL is noted, a small volume of NAPL will be collected for field measurements and observations. The field measurements will include density, viscosity, and temperature. Qualitative observations of NAPL wettability will be made by checking the spreading of NAPL injected into separate beakers containing glass beads, sand, and rock fragments. These observations will be documented using notes and photographs.

To minimize the potential for cross-contamination, perimeter wells or piezometers where NAPL is not expected will be surveyed first, followed by wells where DNAPL is known or expected to be present. All field activities and laboratory programs included in this workplan will be conducted in accordance with the Sauget Area 1 Field Sampling Plan and Quality Assurance Project Plan.

As requested by the EPA, NAPL recovery tests will be conducted as part of Task 2. For planning purposes, it is assumed that Task 2 will include NAPL recovery tests at up to three existing monitoring wells or piezometers per site (i.e., at a total of up to 12 locations in Sauget Area 1), at the locations that have the thickest accumulations of DNAPL. If possible, the recovery tests will be conducted at locations where free-phase NAPL is present with a thickness of at least 0.5 foot.

A container of NAPL will be collected at each existing well or piezometer where a recovery test is conducted, and a composite sample of NAPL from each site (i.e., Sites G, H, I, and L) will be prepared and submitted for laboratory analysis of physical and chemical properties. Recovery test procedures and the laboratory testing program are described in more detail under Task 5.

Task 3: Geophysical Survey

A three-dimensional seismic reflection survey will be conducted to map the topography of the bedrock surface in order to identify topographic lows where free phase DNAPL could potentially accumulate. The geophysical survey will cover an L-shaped area approximately 44.3 acres in size encompassing Sites G, H, I, and L. The geophysical subcontractor will conduct the following work program:

Downhole Surveys: Check-shot surveys and geophysical well logging will be conducted in at least two existing monitoring wells located within the survey area to measure near-surface seismic velocities and to generate seismic travel time to depth relationships for geologic horizons. This information will aid in generating a site velocity model, which will be used to process and interpret the surface seismic data.

3-D Seismic Survey: Prior to the seismic survey, a land survey will be conducted using GPS to establish the geophone positions for the seismic survey grid. The seismic survey will be conducted with a truck-mounted Vibroseis system, a network of geophones and cables, and a high-speed data acquisition and recording instrument. The 3-D survey will likely be collected using 55-foot line intervals at a 605-foot by 605-foot active array of geophones. Testing will be coordinated with data processing personnel who electronically receive the test data from the site and evaluate the field records at a workstation, in order to ensure that the acquired data are of the best quality to meet the project objectives.

Data Processing and Interpretation: The seismic reflection data will be processed and analyzed in various stages using a UNIX workstation and a seismic data processing software package. Processing steps will include the following: editing field data, creating a geometry file, deconvolution (if required), FK filtering (if required), noise attenuation, common midpoint sorting,

velocity analysis, normal moveout corrections, static corrections, mute, trace balancing, common midpoint stacking, digital filtering, and 3-D migration of the seismic reflection data. Interpretation of the seismic data will involve the integration of background information from the site with the seismic images and the downhole data to create structural interpretations of the bedrock surface. Cross section and plan views of the data will be generated to show the configuration of the bedrock surface.

Survey Report: The seismic survey report will include the following: a summary of all activities performed during the project, an overview of seismic reflection theory, summary of data collection methodology, and results of data interpretations. The report will include interpreted cross section, plan-view, and 3-D visualization plots necessary for mapping the bedrock surface. This report will be included as an appendix to the DNAPL Characterization and Remediation Report (see Task 9).

Task 4: Soil Sampling and Installation of Piezometers

Goals of Task 4: The goals of Task 4 are i) to characterize the nature and extent of residual and free-phase DNAPL potentially present within the fill areas and within the upper, middle, and deep hydrogeologic units underlying the fill areas; ii) to investigate for the possible presence of pooled DNAPL in topographic lows on the bedrock surface; and iii) to evaluate the potential extent of residual and free-phase DNAPL outside the boundaries of the fill areas.

Proposed Number of Soil Sampling and Piezometer Locations: Soil sampling and piezometer installation will be conducted at up to 18 locations (see discussion in the paragraph below). Twelve of the soil boring and piezometer locations (three each at Sites G, H, I, and L) are primarily intended for characterizing the nature and extent of DNAPL within the waste materials and underlying hydrogeologic units. These borings will be within the fill areas at locations near the north, south, and west boundaries of the fill areas. Another three soil boring and piezometer locations are primarily intended for investigation of topographic lows in the bedrock surface (i.e., to determine whether pooled DNAPL is present in the topographic lows). These three locations will be selected based on results of the seismic reflection survey (Task 3). The final three soil boring and piezometer locations are primarily intended for evaluating the potential extent of DNAPL outside the boundaries of the fill areas. These three locations will be selected following completion of the initial DNAPL and LNAPL survey and recovery tests (Task 2).

Possible Reduction in Scope of Task 4 Depending on Results of Task 2: According to Table 4-0c, free phase NAPL is reported to be widespread and present at locations well beyond the boundaries of Sites G, H, I, and L. If results of the NAPL survey and recovery tests included in Task 2 confirm that NAPL is as widespread as reported in Table 4-0c, then the large volume estimates for DNAPL-containing waste materials and underlying aquifer that are discussed in the Conceptual Site Model (see Section 2.0) will have been confirmed. In this case, there may not be a need to further characterize the nature and extent of DNAPL at one or more of the Sauget Area 1 sites. Immediately following completion of the NAPL survey and recovery tests

in Task 2, a determination will be made, in consultation with EPA, regarding how many soil boring and piezometer locations are appropriate for Task 4. At a minimum, Task 4 will include soil sampling and piezometer installation at the following locations: i) three proposed locations that are primarily intended for investigation of topographic lows in the bedrock surface; and ii) three proposed locations that are primarily intended for evaluating the potential extent of DNAPL outside the boundaries of the fill areas.

Drilling and Collection of Soil Cores: At the selected soil boring locations, continuous soil coring will be conducted using the sonic drilling method. Each boring will be continuously cored through the fill materials, the alluvial deposits, and five feet into bedrock, to an estimated total depth of 110 feet below grade. During drilling, a 4-inch diameter core barrel will be advanced to collect continuous soil cores. A 6-inch diameter steel over-ride casing will be advanced over the inner drill rods and core barrel to stabilize the borehole and minimize cross-contamination between intervals. In addition, a 7-inch diameter over-ride casing will be used to isolate the fill materials. After retracting each core barrel from the borehole, the core will be extruded into a plastic sleeve for examination and screening. Prior to conducting sample examination or screening, the supervising geologist/engineer will split the core. Half of the core will be segregated in 2-foot intervals, placed into plastic ziplock bags, and stored on ice for potential laboratory analysis. The other half of the core will be examined for soil classification and screened for the possible presence of NAPL.

Soil Core Examination and NAPL Screening: Examination and screening procedures for each core will include the following: visual inspection of the core surface for NAPL staining or droplets; inspection for staining along a strip of flexible reactive liner material (i.e., a NAPL FLUTE strip) placed along the core surface; measurement of headspace vapor concentrations using a photoionization detector (PID) from samples taken at 2-foot intervals; use of shake tests to look for separation of NAPL or a NAPL sheen, followed by addition of Sudan IV dye. Each core will also be examined to determine soil type, using the Unified Soil Classification System (USCS). All cores will be digitally photographed. Each core photograph will include a scale, sample ID, and date of collection.

Selection of Soil Samples for Physical Properties Testing: Three relatively undisturbed soil samples will be retained from each boring for measurement of physical properties, including porosity, bulk density, and grain size classification. A total of three "clean" soil samples (i.e., with little or no evidence of NAPL) will be retained from each boring for analysis of fraction organic carbon.

Selection of Soil Samples for DNAPL Mobility Evaluation: At each of the four fill areas (i.e., Sites G, H, I, and L), one relatively undisturbed fill or soil sample will be collected from each subsurface unit (contaminated fill material and shallow, middle, and deep hydrogeologic units). The samples will be collected using a split-spoon sampling device at depth intervals where DNAPL-affected soils are likely to be present, based on information from historical boring logs and NAPL screening results. The core samples will be placed on dry ice and submitted to PTS Laboratories of Houston, Texas, for evaluation of DNAPL mobility using a modified centrifuge

test procedure (ASTM D425M). The test results will include initial and residual pore fluid saturations, total porosity, dry bulk density, and visual indications of produced fluids.

Selection of Soil Samples for Lab Testing for Chemical Constituents: One soil sample from each 10-foot interval of core will be retained for laboratory analysis of chemical constituents. Duplicate soil samples will be collected at a ratio of one per ten soil samples, and matrix spike/matrix spike duplicate pairs will be collected at a ratio of one set per twenty soil samples. If NAPL is noted in a soil core based on visual inspection or examination of NAPL FLUTE strips, the soil sample retained for laboratory analysis will be from the portion of the core that has the most obvious visual indications of NAPL. If there are no visual indications of NAPL in the 10-foot interval of core, the soil sample for laboratory analysis will be from an interval exhibiting noticeably higher organic vapor levels than the rest of the core, as measured by PID headspace readings. If headspace readings are relatively uniform along the core, then the soil sample will be taken from approximately the midpoint of the core.

Analytical Program for Chemical Constituents: Soil samples will be placed in appropriate containers, and methanol will be used as a preservative for the samples that are retained for analysis of VOCs. The samples will be stored on ice and shipped to Severn Trent Laboratories (STL) in Savannah, Georgia. STL will test each soil sample for TOC, VOCs, and SVOCs. TOC analyses will be used to determine the total mass of organic constituents in each soil sample. VOC and SVOC analyses will be used to chemically characterize the organic constituents present in the soil samples. VOCs and SVOCs were selected as analytical parameters for chemical analyses because groundwater data collected during the Sauget Area 1 Support Sampling Plan indicate that these are the most mobile constituents in groundwater at Sites G, H, and I. These data, along with representative measured values of porosity and fraction organic carbon, will be analyzed to obtain an estimate of DNAPL saturation (percent of pore space containing DNAPL) for each sampling point.

Three or four samples per fill area (i.e., Sites G, H, I, and L) will be placed on dry ice and submitted to PTS Laboratories in Houston, Texas for analysis of pore fluid saturations using the standard Dean-Stark test procedure (API RP 40), which includes determination of initial fluid saturations, total porosity, bulk density, and air-filled porosity. The Dean-Stark test results will provide a direct measurement of DNAPL saturation that can be used as an independent verification of the calculation approach using the VOC, SVOC, and TOC test results.

Installation and Development of Piezometers: After reaching the target depth, each boring will be completed as a piezometer to determine if free-phase DNAPL is present and, if so, to measure the thickness of the DNAPL. The piezometers will be screened both above and below the bedrock surface and will be constructed of 2-inch diameter PVC casing with 15 feet of stainless steel wire-wound screen. After the screen and casing are installed in the borehole, the sandpack, bentonite seal, and grout seal will be placed as the six-inch diameter over-ride casing is retracted from the borehole. Each piezometer will be developed by air-lift pumping, bailing, or another approved method. Following completion of development, the depth to water and total depth of each piezometer will be measured, and each piezometer will be checked for the possible presence of NAPL using an interface probe, weighted cotton string, and Teflon bailer.

To allow for possible accumulation of NAPL, each new piezometer will be left undisturbed for a period of at least one week prior to conducting the work described under Task 5.

Management of Investigation-Derived Waste: All investigation-derived wastes generated during drilling, soil sampling, and piezometer development will be placed in designated containers for management by Solutia.

Task 5: NAPL Recovery Tests and NAPL Analyses

NAPL Recovery Tests and Field Observations of NAPL: The piezometers installed during Task 4 will be surveyed again for the possible presence of DNAPL or LNAPL using the interface probe, weighted cotton string, and Teflon bailer. A NAPL recovery test will be conducted at each new piezometer which has a confirmed thickness of free-phase NAPL of at least 0.5 foot. For planning purposes, it is assumed that Task 5 will include a total of up to 15 NAPL recovery tests.

The recovery tests will be performed using inertial lift pumping equipment with disposable downhole components (i.e., Waterra tubing and foot valves). The pumping rate will be set to minimize the volume of water pumped from the well by performing a visual inspection of fluid samples collected in closed flasks. The volume of DNAPL and the volume of water produced will be recorded at 15-minute intervals. It is anticipated that the recovery tests will be conducted using alternating periods of pumping and resting. If NAPL volume in the recovered fluids decreases substantially after an initial period of pumping, then pumping will be stopped temporarily to allow time for additional NAPL to enter the well screen and accumulate in the well. The NAPL recovery test at a well will be terminated when at least one of the following conditions is met: i) the recovery test at a well has been conducted for at least 8 hours; ii) a total of at least 100 gallons of fluids has been recovered from a well; or iii) no measurable NAPL has been recovered from a well during at least two consecutive pumping and rest cycles following the initial pumping period.

The volume of NAPL and volume of water recovered during each test will be determined by measuring accumulations in a collection vessel such as a closed tank or drum. A container of NAPL and water will be collected at each new piezometer where a recovery test is conducted, and a composite sample of NAPL and water from each site (i.e., Sites G, H, I, and L) will be prepared and submitted for laboratory analysis of physical and chemical properties. Each composite sample will consist of the following: four one-liter samples of NAPL, four 10-mL vials (or equivalent) of NAPL, and a one-liter sample of water. These sample containers will be retained for: i) laboratory analysis of physical properties and chemical composition, and ii) bench-scale treatability testing (see Task 6).

Qualitative observations of NAPL wettability will also be made by checking the spreading of NAPL injected into separate beakers containing glass beads, alluvial aquifer materials, and bedrock fragments. These observations will be documented using notes and photographs. At

the conclusion of each recovery test, the well or piezometer will be resurveyed for the presence of NAPL using the interface probe, weighted cotton string, and a Teflon bailer.

Laboratory Testing of NAPL for Physical Properties and Chemical Composition: Of the containers that comprise each composite sample, one liter of NAPL and one liter of water will be submitted for laboratory analysis of fluid properties at PTS Laboratories in Houston, Texas. These samples will be tested using ASTM D445 and ASTM D1481, which include measurement of: i) dynamic viscosity and fluid density at three temperatures; ii) surface tension for each fluid; and iii) interfacial tension for oil/water, oil/air, and water/air. The four 10-mL vials of NAPL from each composite sample will be submitted to Severn Trent Laboratories in Savannah, Georgia, for laboratory analysis of chemical composition. These samples will be analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxin, and metals (including mercury). The laboratory analyses will indicate the major chemical components of the NAPL, on a percentage basis.

Management of Investigation-Derived Waste: All investigation-derived wastes generated during the NAPL recovery tests will be placed in designated containers for management by Solutia.

Task 6: Bench-Scale Treatability Tests

Bench-scale treatability tests will be conducted for thermal treatment, for surfactant addition, and, if feasible, for in-situ chemical oxidation. The results from these tests will provide design information for evaluating the applicability and potential effectiveness of thermal, surfactant-based, and chemical oxidation technologies.

Thermal Treatability Test: A total of four composite samples of NAPL (one each from Sites G, H, I, and L) that are collected during either Task 2 or Task 5 will be analyzed to generate boiling point curves using ASTM D-86 (Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure). This test will provide boiling point data up to 750 degrees Celsius. However, any tars or other material with boiling points above this range will not be measured.

Test results will indicate if temperatures that can be achieved by applicable thermal treatments (such as steam addition) can remove sufficient residual and free-phase NAPL from the subsurface. Note that the results from this treatability test will only indicate the theoretical technical performance of thermal treatment. Practical and engineering constraints that may limit the application of the technology will be addressed in Task 7.

Surfactant Treatability Test: Samples of the NAPL will be analyzed for key physical and chemical properties as part of Tasks 2 and 5. Using these data, a representative sample of NAPL will be selected from available samples and used for all the surfactant bench-scale tests.

A literature review will be performed to identify promising surfactants that could be used for remediation. Key criteria for selecting the surfactants will be i) experience at other surfactant sites; ii) risk associated with addition to subsurface (i.e., a food-grade surfactant will likely be required); and iii) compatibility with local water quality conditions.

Each surfactant will be evaluated by:

1. Adding NAPL to water in beaker or closed jar and gently mixing.
2. Sampling and analyzing the aqueous phase for VOCs and SVOCs.
3. Adding surfactant slowly and mixing until the critical micelle concentration (CMC) is observed visually (i.e., by a noticeable change in appearance of the aqueous phase).
4. Taking selected measurements of NAPL-water interfacial tension as surfactant concentration is increased to the CMC.
5. Analyzing post CMC aqueous phase for VOCs and SVOCs.

Each surfactant will be tested at two ionic strengths. The test results will indicate how much surfactant is required to achieve the CMC in the subsurface.

Chemical Oxidation Treatability Evaluation: Using data on NAPL chemical composition taken from Tasks 2 and 5, calculations will be performed to determine the mass of various oxidants required to oxidize a given mass of NAPL from the site. The calculations will be repeated at different pH values to evaluate the sensitivity of various oxidants to pH. If the design information indicates that chemical oxidation is feasible, then bench-scale oxidation tests of the most promising oxidant acting on the NAPL can be performed in a later phase to confirm the results of the calculations.

A short data report will be developed to summarize results from the bench-scale treatability tests and chemical oxidation treatability evaluation. This report will be included as an appendix to the DNAPL Characterization and Remediation Report (see Task 9).

Task 7: Review of DNAPL Source Depletion Alternatives

An analysis of whether active DNAPL source depletion technologies are applicable to Sauget Area 1 will be conducted. The analysis will focus on three aggressive source treatment technologies: i) thermal treatment, ii) surfactant treatment, and iii) in-situ chemical oxidation.

This analysis will focus on three key factors:

Performance: An assessment of the potential performance of thermal treatment, surfactant treatment, and chemical oxidation will be made using data from the bench-scale treatability tests performed as part of Task 6, and from observed performance at pilot-scale tests and full-scale tests reported at other sites. GSI will rely on existing literature data to develop cost and generic performance information for the three source removal technologies.

Actual performance of thermal treatment, surfactant treatments, and chemical oxidation in a full-scale field application at the Sauget 1 area will be estimated. The potential for rebound of dissolved-phase concentrations and the potential need for continued management of the dissolved-phase plume after treatment will also be evaluated.

Cost: GSI will use unit costing approaches in the literature based on area, volume, and depth to develop planning-level costs for application of the three treatment approaches. For surfactants, the Advanced Applied Technology Demonstration Facility's (AATDF) design manual for surfactant treatment will be used as a primary costing resource. For thermal treatment, costs reported in the literature for full-scale applications will be developed. Costs will be adjusted to reflect site-specific conditions, such as a deep saturated unit (> 100 feet), and the need to drill through waste units.

Engineering Considerations: Practical engineering considerations such as access, safety issues, and other factors will be assessed in the application of thermal treatment, surfactant treatment, and chemical oxidation.

In addition, an analysis of the relative mass flux originating from leachate migration and from DNAPL dissolution will be performed using dissolved-phase concentration data and groundwater flowrate estimates. This analysis will indicate the relative contribution of leachate and DNAPL dissolution on the total mass flux leaving the source zone.

Task 8: Remedial Alternatives Evaluation

An updated evaluation of remedial alternatives for Sauget Area 1 will be performed based on the findings from Tasks 2 through 7 of this work program and results of previous remedial alternative analyses documented in earlier site reports. The evaluation will result in a comparison of the costs, benefits, and engineering considerations of the following remedial alternatives:

- Natural Attenuation (from Sauget Area 1 EE/CA and RI/FS Report).
- Capping Source Areas (from Sauget Area 1 EE/CA and RI/FS Report).
- Physical Barrier at Mississippi River (from Sauget Area 1 EE/CA and RI/FS Report, Sauget Area 2 Interim Groundwater Remedy FFS, and capture zone modeling of the Sauget Area 2 Interim Groundwater Remedy using a particle tracking model).
- Aggressive Pump-and-Treat at Sauget Area 1 Source Areas (Sites G, H, and I) (from Sauget Area 1 EE/CA and RI/FS Report).
- In-Situ Treatment of Source Areas and Aquifer Matrix (for the most promising source depletion alternative identified in Tasks 6 and 7 of this work program).

A simple source model, originally developed as part of the BIOSCREEN model (Newell et al., 1996, EPA/600/R-96/087) and now being included as part of the BIOCHLOR model (Aziz et al., 2000 (EPA/600/R-00/008), was used to estimate the lifetime of the groundwater source at Sauget Area 1 Site I under different remediation options in the Sauget Area 1 EE/CA and RI/FS Report (see Attachment 2 - Sauget Area 1 Source Evaluation Study, May 21, 2001).

In this simple box model, the source zone is considered to be located in a box containing some mass of dissolvable contaminants. The rate at which contaminants leave the box is estimated from the rate at which flowing groundwater removes contaminants from the box. The time required to achieve a cleanup standard can then be estimated by comparing the mass of

contaminants in the box vs. the time to remove contaminants from the box. To more closely match real site conditions, the source concentration is assumed to decay over time in proportion to the remaining source mass (Wiedemeier et al., 1999).

Predicting DNAPL source zone response is an active research area and current research is summarized in the Technical Memorandum "Applicability of Uniform Concentration to Mass Ratio Assumption" (Attachment 3). Some research indicates that a large volume of DNAPL mass removal is required to achieve a small reduction in DNAPL dissolution (flux). Other research indicates that a small volume of DNAPL removal can achieve a large reduction in DNAPL dissolution. The model used in the Sauget Area 1 Source Evaluation Study is based on the assumption that dissolved groundwater concentrations are directly proportional to DNAPL reductions, which is supported by research performed by Newell et al. (1996).

As can be seen in Figure 1 of the Technical Memorandum (Attachment 3), the model assumption used in the Sauget Area 1 Source Evaluation Study (changes in constituent concentrations in groundwater are directly proportional to changes in DNAPL mass) will result in time to clean predictions that are roughly midway between time to clean predictions based on the low DNAPL mass removal/high flux reduction assumptions of Rao and Jawitz (2003) and Enfield et al. (2002) and the high DNAPL mass removal/low flux reduction assumptions of Rao et al. (1997) and Sale and McWhorter (2001). For this reason, it is considered appropriate to use the Sauget Area 1 DNAPL Dissolution Model (as described in the Source Evaluation Study) in Task 8 - Remedial Alternatives Evaluation of the DNAPL Characterization and Remediation Study. This model will be used to make a time to clean estimate for each of the remedial alternatives to ensure an effective and objective comparative analysis of all of the remedial alternatives.

To provide a bounding or sensitivity analysis that could be useful in remedy evaluation, including assessment of the suitability of a Technical Impracticability Waiver for the Sauget Area 1 Sites, time to clean estimates will also be made using the Rao and Jawitz (2003) conceptual DNAPL dissolution model (small volume of DNAPL removal/large reduction in groundwater concentrations) and the Sale and McWhorter (2001) conceptual model (large volume of DNAPL removal/small reduction in groundwater concentrations).

The DNAPL Characterization and Remediation Study will include the time to clean calculations and results based on each of the three widely different DNAPL dissolution conceptual models reported in the literature (as described above and in Attachment 3) so that the uncertainty associated with estimates of DNAPL remediation time frames at the Sauget Area 1 Sites are identified and discussed in the final report.

Task 9: Project Report

A project report will be prepared to include these elements:

- Summary of all field activities
- Map of wells and piezometers showing measured values of DNAPL thickness

- Structural map showing top-of-bedrock topography based on geophysical survey
- Structural map(s) showing tops of laterally continuous low-permeability clay layers within the alluvial aquifer, if any such layers are present.
- Profiles of DNAPL distribution vs. depth for soil borings
- Two stratigraphic cross sections
- Summary of DNAPL physical and chemical properties
- DNAPL recoverability test results and interpretation
- DNAPL mobility test results and interpretation
- Bench-scale treatability test results and interpretation
- Results from DNAPL source depletion alternatives study
- Results of remedial alternatives evaluation
- Bedrock transport analysis (based on core inspection and technical literature)
- Possible timing of DNAPL releases (based on review of historical site information)
- Appendix – Report from geophysical contractor
- Appendix – Soil boring logs
- Appendix – As-built diagrams for piezometers
- Appendix – Laboratory data
- Appendix – Bench scale treatability test data report

5.0 SCHEDULE

It is anticipated the entire project could be completed within approximately six months of notice to proceed, in accordance with the estimated timeline outlined below. If possible, field work involving Level B PPE will not be scheduled during hot summer months. Note that the schedule calls for soil sampling and piezometer installation (Task 4) to be conducted in two separate mobilizations. The second mobilization will be for soil sampling and piezometer installation to investigate up to three topographic lows in the bedrock surface, which cannot be identified until the geophysical survey report (Task 3) is completed.

Task 1	Project Startup and Contractor Scheduling	Weeks 1 and 2
Task 2	NAPL Survey (all wells) and Recovery Tests (12 wells) Laboratory Analysis of NAPL samples	Weeks 3 and 4 Weeks 3 through 7
Task 3	Geophysical Survey (field data collection) Geophysical Survey (processing, interpretation, report)	Weeks 4 through 6 Weeks 7 through 15
Task 4	Soil Sampling / Piezometer Installation (12 locations) Soil Sampling / Piezometer Installation (3 locations) Laboratory Analysis of Soil Samples	Weeks 7 through 10 Week 16 Weeks 7 through 18
Task 5	NAPL Recovery Tests (12 new piezometers) NAPL Recovery Tests (3 new piezometers) Laboratory Analysis of NAPL samples	Weeks 11 and 12 Week 17 Weeks 11 through 19
Task 6	Bench-Scale Treatability Tests	Weeks 13 through 16
Task 7	Review of DNAPL Source Depletion Alternatives	Weeks 17 through 20
Task 8	Remedial Alternatives Evaluation	Weeks 19 through 22
Task 9	Project Report (including review and submittal to EPA)	Weeks 17 through 26

WORKPLAN FOR DNAPL CHARACTERIZATION AND REMEDIATION STUDY

Sauget Area 1 Sites
Sauget, Illinois

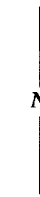
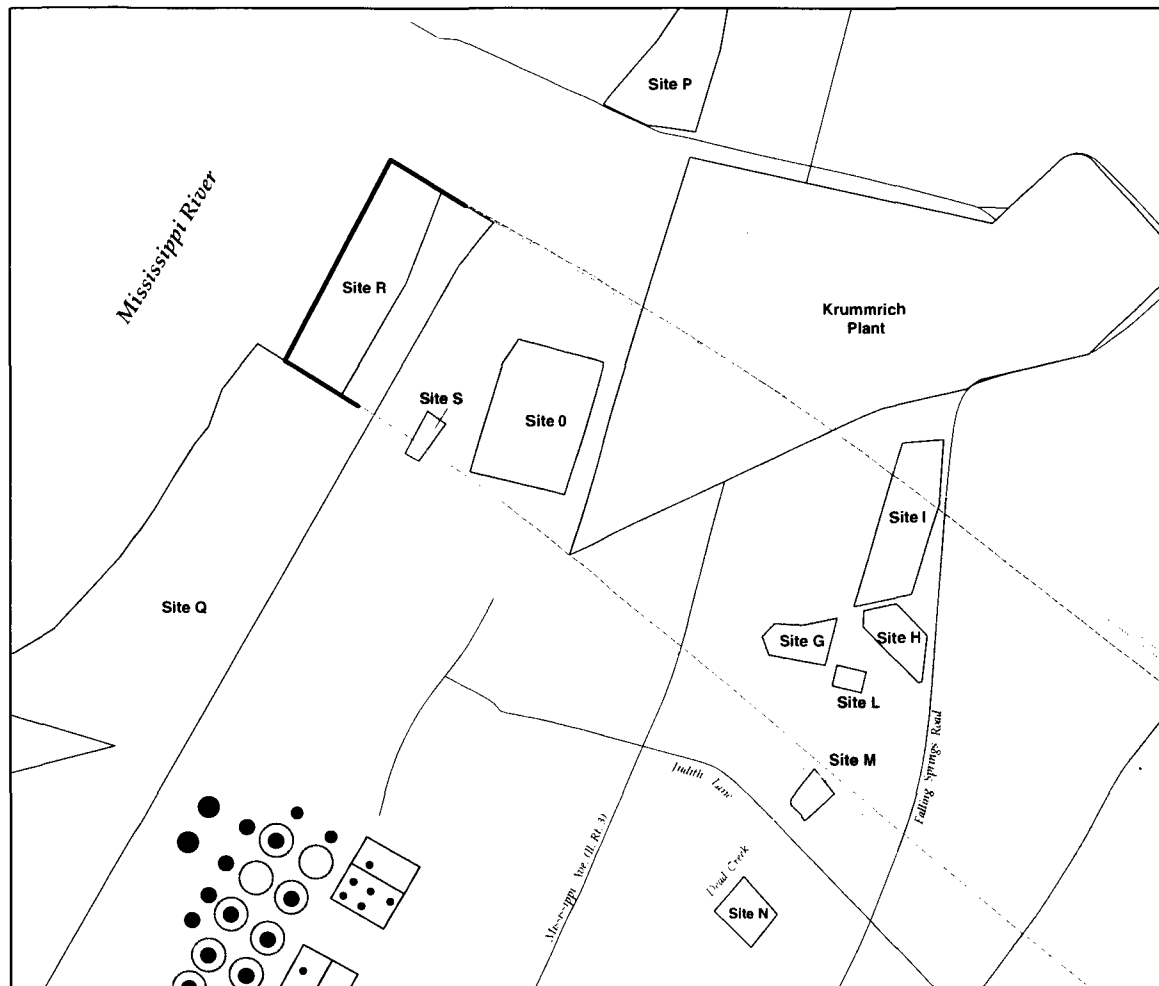
Figures and Table

Figure Number and Title

- Figure 1: Capture Zone Maps for Groundwater Alternative B – Physical Barrier
- Figure 2: Estimated Extent of DNAPL from Table 4-0c
- Figure 3: Estimated Extent of DNAPL from 1% Rule
- Figure 4: Conceptual Site Model of DNAPL Distribution

Table Number and Title

- Table 1: List of Monitoring Wells and Piezometers at Sauget Area 1



LEGEND

- Shallow Hydrogeologic Unit Capture Zone Boundary
- - - Middle Hydrogeologic Unit Capture Zone Boundary
- - - Deep Hydrogeologic Unit Capture Zone Boundary
- Jet-Grouted Barrier Wall
- Saugeat Area 1
- Saugeat Area 2

NOTES:

- 1) Based on MODFLOW modeling described in Focused Feasibility Study, Volume 1, Interim Groundwater Remedy Saugeat Area 2 Sites O, Q, R and S, Solutia, Inc., March 31, 2002, "Groundwater Interim Remedy Design Basis", and MODPATH modeling.
- 2) Physical barrier includes 3 partially extraction pumping wells pumping at combined pumping rate of 535 gpm.
- 3) Modeling performed using average river stage (391 ft. AMSL). All other values from baseline modeling run.
- 4) Base map from Figure 1, Focused Feasibility Study, Volume 1, Interim Groundwater Remedy Saugeat Area 2 Sites O, Q, R and S, Solutia, Inc., March 31, 2002.
- 5) River boundary changes with river stage. River boundary on this map is approximate.

SCALE (ft.)
0 500 1000

PRELIMINARY

FIGURE 1

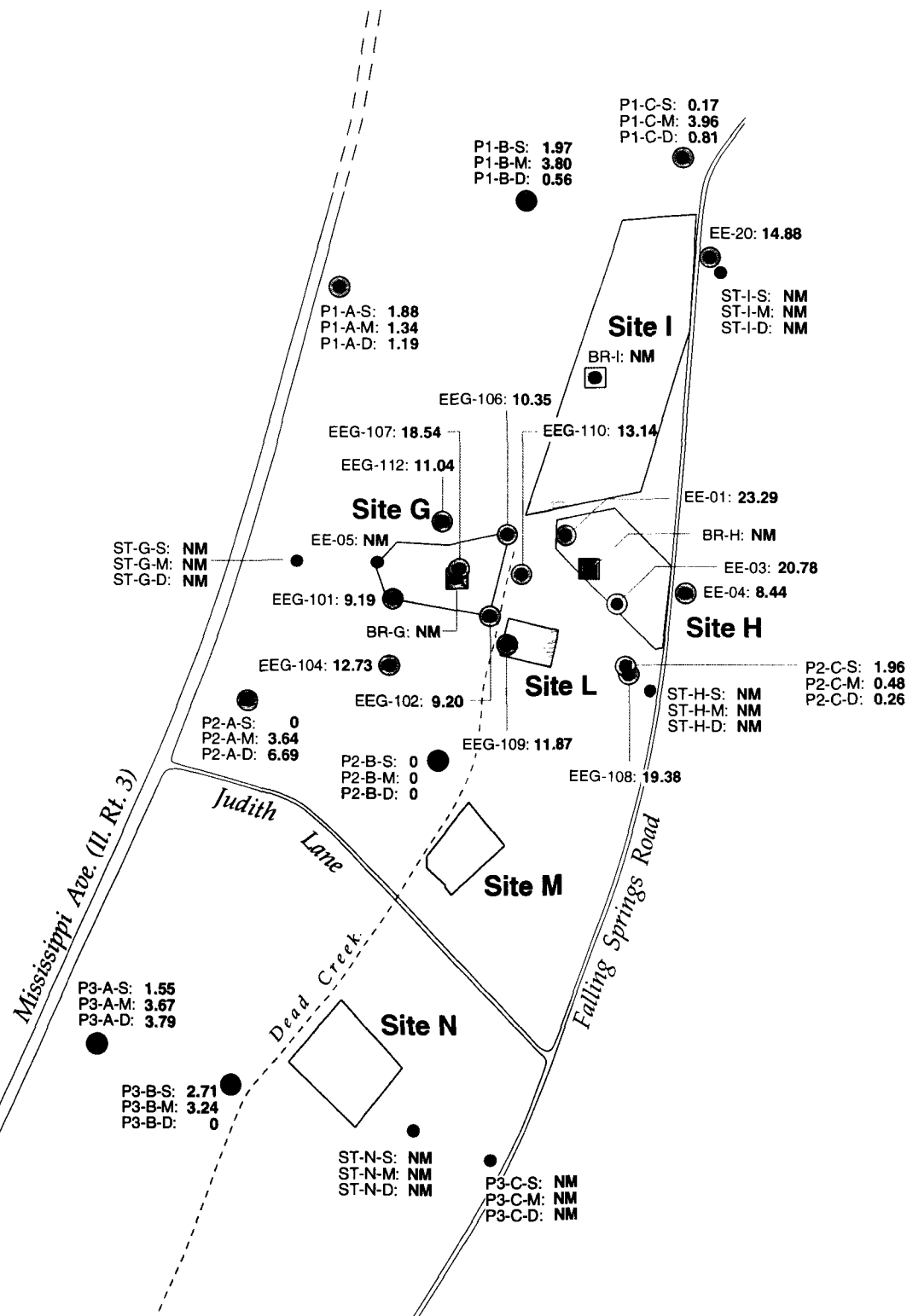


GSI Job No. G-2561
Issued 4/01/02
Revised
Scale As Shown

Drawn By CCJ
Chkd By CJN
App'd By
FIGURE 1

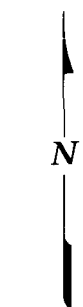
**CAPTURE ZONE MAPS FOR GROUNDWATER
ALTERNATIVE B-PHYSICAL BARRIER**
Saugeat Area 2, Saugeat Illinois

Mississippi
River



SCALE (ft.)

0 400 800



LEGEND

- Monitoring well or piezometer location
- Bedrock monitoring well where DNAPL was observed during groundwater sampling
- Bedrock monitoring well where potential presence of DNAPL was noted during groundwater sampling
- Bedrock monitoring well where no indication of DNAPL was noted during groundwater sampling
- Monitoring well or piezometer where DNAPL was reported to be present according to Table 4-0c
- Monitoring well or piezometer where DNAPL was reported to be absent according to Table 4-0c
- (18.54) DNAPL thickness reported on Table 4-0c.
- (NM) No information listed on Table 4-0c for this well or piezometer

Note:
Table 4-0c is from a report prepared by the U.S. Army Corps of Engineers and is based on review of field notes recorded during measurement of water levels as part of the Area 1 investigation in 1999 and 2000.

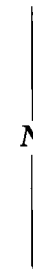


ESTIMATED EXTENT OF DNAPL FROM TABLE 4-0C

Sauget Area 1, Sauget and Cahokia, Illinois

GSI Job No:	G-2876	Drawn By:	DLB
Issued:	4/01/04	Chk'd By:	JAK
Revised:		App'd By:	
Scale:	As Shown		FIGURE 2

Mississippi
River

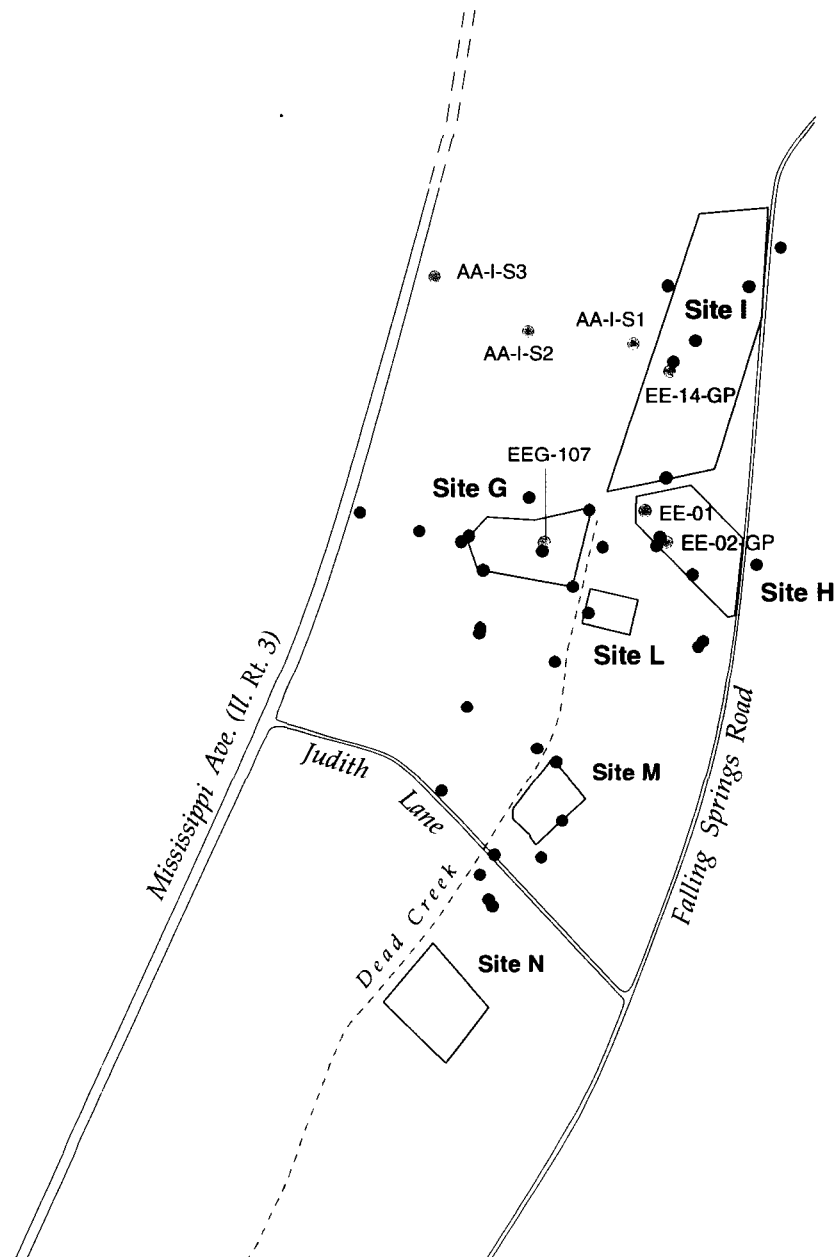


LEGEND

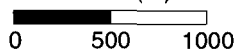
- Total VOCs concentration in groundwater is greater than or equal to 4.45 mg/L. Use of "1% rule" suggests that free-phase or trapped DNAPL may be present (see Note 1)
- Total VOCs concentration in groundwater is less than 4.45 mg/L. Use of "1% rule" suggests that DNAPL is not present

Notes:

- 1) On this figure, DNAPL is inferred to be present at locations where the concentration of total VOCs in groundwater exceeds 1% of the pure phase solubility of chlorobenzene, a VOC which is detected at elevated levels at Sauget Area 1.
- 2) Concentrations of total VOCs in groundwater were taken from Figure 4-18 of "Engineering Evaluation/Cost Analysis and Remedial Investigation/Feasibility Study," Sauget Area 1, Revision 1, June 8, 2001.
- 3) A value of 445 mg/L was used for solubility of chlorobenzene in water (see Wiedemeier, T.H., Rifai, H.S., Newell, C.J., and Wilson, J.W., 1999. *Natural Attenuation of Fuels and Chlorinated Solvents*, John Wiley & Sons, New York). Accordingly, 1% of solubility of chlorobenzene is 4.45 mg/L.



SCALE (ft.)



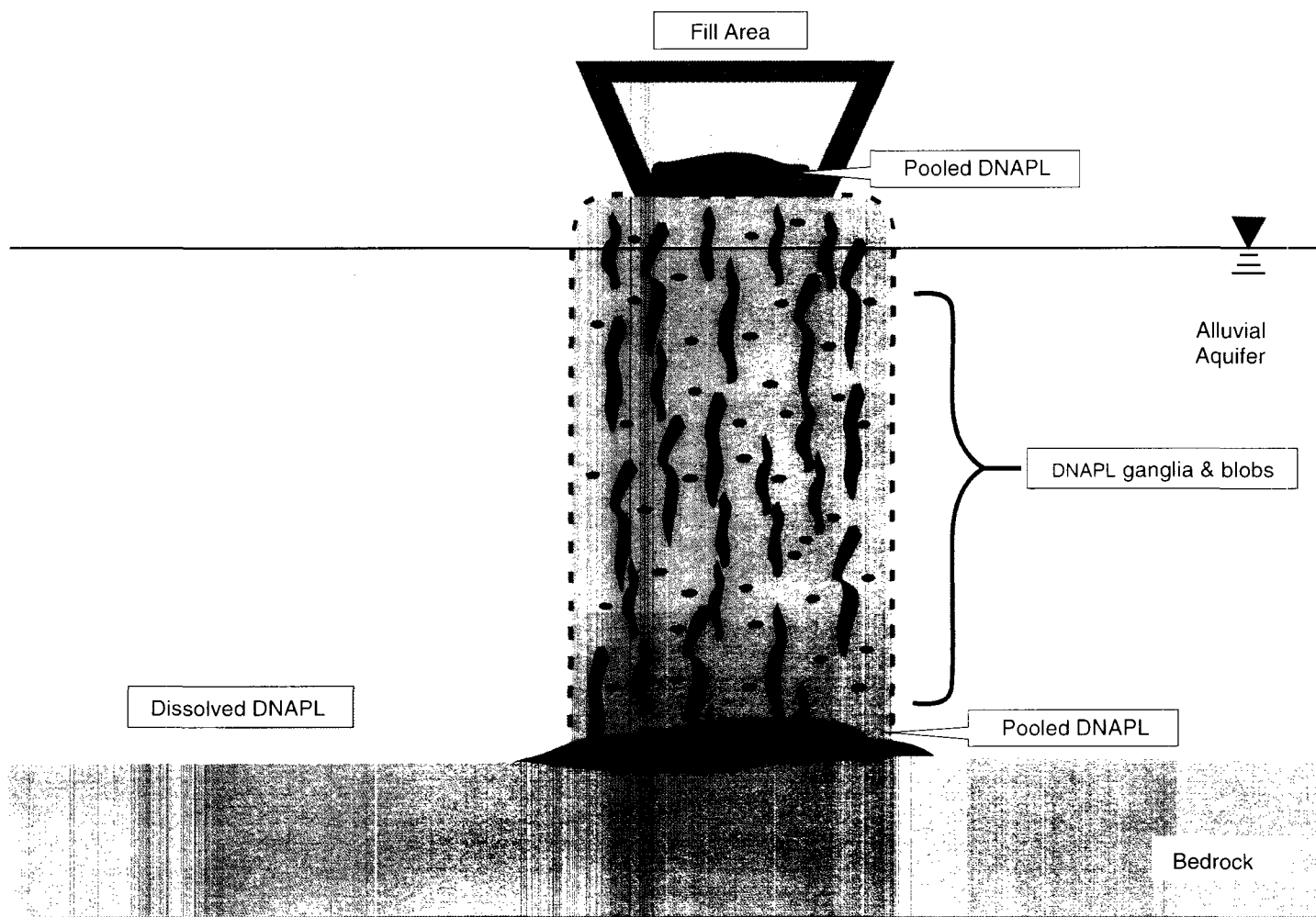
GSI Job No. G-2876
Issued: 4/01/04
Revised: _____
Scale: As Shown

Drawn By: DLB
Chk'd By: JAK
Apr'd By: _____

FIGURE 3

ESTIMATED EXTENT OF DNAPL FROM 1% RULE

Sauget Area 1, Sauget and Cahokia, Illinois



GSI Job No. G-2876

Issued 4/1/04

Scale Not to Scale

Drawn By CRW

Chk'd By JAK

FIGURE 4

CONCEPTUAL SITE MODEL OF DNAPL DISTRIBUTION

Sauget Area 1
Sauget and Cahokia, Illinois

TABLE 1
List of Monitoring Wells and Piezometers at Sauget Area 1
 Sauget Area 1 Sites, Sauget, Illinois

	Approximate Total Depth of Well (ft bgs)	Hydrogeologic Unit	Reported DNAPL Thickness from Table 4-0c (ft)	Notes
Site G				
BR-G	-	Bedrock	NM	
EE-05	23	Fill	NM	
EEG-101	21.85	Fill	9.19	
EEG-102	20.52	Fill	9.20	
EEG-104	24.21	Shallow	12.73	
EEG-106	19.60	Fill	10.35	
EEG-107	28.46	Fill	18.54	
EEG-112	21.23	Shallow	11.04	
ST-G-S	-	Shallow	NM	
ST-G-M	-	Middle	NM	
ST-G-D	-	Deep	NM	
Site H				
BR-H	-	Bedrock	NM	
EE-01	32.75	Fill	23.29	
EE-02	23	Fill	NM	Cannot be sampled
EE-03	32.80	Fill	20.78	
EE-04	22.31	Shallow	8.44	
EEG-110	23.64	Shallow	13.14	
P2-C-S	10.05	Shallow	1.96	
P2-C-M	38.60	Middle	3.45	
P2-C-D	58.59	Deep	0.26	
ST-H-S	-	Shallow	NM	
ST-H-M	-	Middle	NM	
ST-H-D	-	Deep	NM	
Site I				
BR-I	-	Bedrock	NM	
EE-12	33	Fill	NM	No longer exists
EE-13	29	Fill	NM	No longer exists
EE-14	37.5	Fill	NM	Cannot be sampled
EE-15	29	Fill	NM	No longer exists
EE-20	27.89	Shallow	14.88	
P1-A-S	22.20	Shallow	1.88	
P1-A-M	40.42	Middle	3.29	
P1-A-D	60.08	Deep	3.33	
P1-B-S	17.13	Shallow	1.97	
P1-B-M	39.74	Middle	3.80	
P1-B-D	59.86	Deep	0.56	
P1-C-S	17.17	Shallow	0.17	
P1-C-M	39.91	Middle	3.96	
P1-C-D	59.58	Deep	0.81	
ST-H-S	-	Shallow	NM	
ST-H-M	-	Middle	NM	
ST-H-D	-	Deep	NM	

TABLE 1
List of Monitoring Wells and Piezometers at Sauget Area 1
 Sauget Area 1 Sites, Sauget, Illinois

	Approximate Total Depth of Well (ft bgs)	Hydrogeologic Unit	Reported DNAPL Thickness from Table 4-0c (ft)	Notes
Site L				
EEG-103	21.5	Shallow	NM	Cannot be sampled
EEG-105	No log	-	NM	No longer exists
EEG-108	28.42	Shallow	19.38	
EEG-109	23.00	Fill	11.87	
ST-L-S	-	Shallow	NM	No longer exists
ST-L-M	-	Middle	NM	No longer exists
ST-L-D	-	Deep	NM	No longer exists
Sites M or N				
EEG-111	No log	-	NM	Cannot be sampled
P2-A-S	18.18	Shallow	None	
P2-A-M	39.23	Middle	3.64	
P2-A-D	59.91	Deep	6.69	
P2-B-S	9.85	Shallow	None	
P2-B-M	39.87	Middle	None	
P2-B-D	59.45	Deep	None	
P3-A-S	14.61	Shallow	1.55	
P3-A-M	39.56	Middle	3.67	
P3-A-D	59.58	Deep	3.79	
P3-B-S	13.13	Shallow	2.71	
P3-B-M	39.10	Middle	3.24	
P3-B-D	55.06	Deep	None	
P3-C-S	-	Shallow	NM	
P3-C-M	-	Middle	NM	
P3-C-D	-	Deep	NM	
ST-N-S	-	Shallow	NM	
ST-N-M	-	Middle	NM	
ST-N-D	-	Deep	NM	

Notes:

- 1) NM = not listed on Table 4-0c from the U.S. Army Corps of Engineers report. Hydrogeologic units include: fill material; the shallow, middle, and deep hydrogeologic units within the alluvial aquifer; and bedrock.
- 2) Table 4-0c lists a well identified as EE-11. This well ID appears to have a typographical error, since there reportedly is no well EE-11 at Sauget Area 1.
- 3) Approximate total depths of wells were taken from Table 4-0c of the U.S. Army Corps of Engineers report or from page 3-9 of the Sauget Area 1 EE/CA and RI/FS report dated June 2001.
- 4) Wells with the prefix ST- were originally installed for the purpose of conducting slug tests and are shown on Figure 4-40 of the Sauget Area 1 EE/CA and RI/FS report.

GSI Job No. G-2876
April 1, 2004



**GROUNDWATER
SERVICES, INC.**

ATTACHMENT 1

Table 4-0c from U.S Army Corps of Engineers Report

Sauget Area 1 Sites
Sauget, Illinois

Table 4-0c. Summary of Field Notes and Observations during Groundwater Monitoring

Well/ Piezometer	Depth to Water (ft BGS)	Depth to top of DNAPL (ft)	Depth to bot of DNAPL (ft)	DNAPL Thickness (ft)	Total Depth (ft)	Comments
EE-01	8.43	9.46	32.75	23.29	32.75	
EE-03	10.93	12.02	32.80	20.78	32.80	
EE-04	12.78	13.87	22.31	8.44	22.31	
EE-11	NA	10.27	NA	Full depth	NA	Well completely full of "brown oily liquid," no water
EE-20	12.09	13.01	27.89	14.88	27.89	
EEG-101	11.63	12.66	21.85	9.19	21.85	
EEG-102	10.25	11.32	20.52	9.20	20.52	
EEG-104	10.36	11.48	24.21	12.73	24.21	
EEG-106	8.20	9.25	19.60	10.35	19.60	
EEG-107	28.46	9.92	28.46	18.54	28.46	
EEG-108	7.97	9.04	28.42	19.38	28.42	
EEG-109	10.09	11.13	23.00	11.87	23.00	
EEG-110	9.42	10.51	23.65	13.14	23.64	
EEG-112	9.11	10.19	21.23	11.04	21.23	
P1-A-S	19.55	20.32	22.20	1.88	22.20	
P1-A-M	20.54	21.60	24.89	3.29		
		36.31	37.71	1.40		
		39.08	40.42	1.34	40.42	
P1-A-D	20.88	22.00	25.33	3.33		
		56.06	57.37	1.31		
		58.89	60.08	1.19	60.08	
P1-B-S	14.35	15.16	17.13	1.97	17.13	
P1-B-M	15.03	16.09	19.44	3.35		
		35.94	39.74	3.80	39.74	
P1-B-D	14.96	56.01	58.57	0.56	59.86	
P1-C-S	16.91	17.00	17.17	0.17	17.17	
P1-C-M	15.88	17.03	20.32	3.29		
		35.95	39.91	3.96	39.91	
P1-C-D	15.79	55.80	56.50	0.70		
		58.77	59.58	0.81	59.58	
P2-A-S	10.94	NA	NA	NA	18.18	

Table 4-0c (continued)

Well/ Piezometer	Depth to Water (ft BGS)	Depth to top of DNAPL (ft)	Depth to bot of DNAPL (ft)	DNAPL Thickness (ft)	Total Depth (ft)	Comments
P2-A-M	11.04	11.98	15.62	3.64	39.23	
P2-A-D	11.06	33.10	38.47	3.37		
		53.22	59.91	6.69	59.91	
P2-B-S	6.84	NA	NA	NA	9.85	
P2-B-M	6.84	NA	NA	NA	39.87	
P2-B-D	6.75	NA	NA	NA	59.45	
P2-C-S	7.30	8.09	10.05	1.96	10.05	
P2-C-M	7.50	8.48	11.93	3.45		
		34.79	36.90	2.11		
		38.12	38.60	0.48	38.60	
P2-C-D	7.98	55.91	56.17	0.28	58.59	
P3-A-S	12.23	13.06	14.61	1.55	14.61	
P3-A-M	12.07	35.89	39.56	3.67	39.56	
P3-A-D	12.19	55.79	59.58	3.79	59.58	
P3-B-S	9.58	10.42	13.13	2.71	13.13	
P3-B-M	9.78	35.86	39.10	3.24	39.10	
P3-B-D	9.64	NA	NA		55.06	

GSI Job No. G-2876
April 1, 2004



ATTACHMENT 2

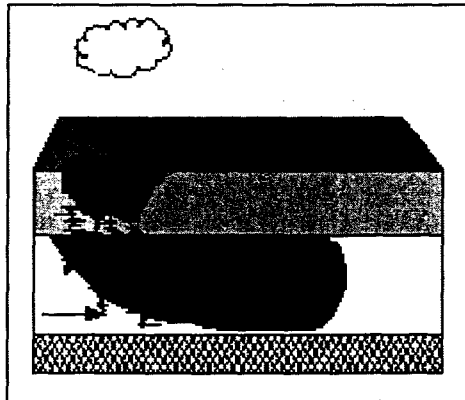
Sauget Area 1 Source Evaluation Study, May 21, 2001

Sauget Area 1 Sites
Sauget, Illinois

SOURCE EVALUATION STUDY

Sauget Area 1

Sauget and Cahokia, Illinois



**Submitted to
Solutia Inc.**

May 21, 2001

Groundwater Services, Inc.
2211 Norfolk, Suite 1000, Houston, Texas 77098

May 21, 2001



EXECUTIVE SUMMARY

An evaluation of the source of impacted groundwater at Site I within Sauget Area 1 was performed to evaluate two questions:

- 1) *What is the dominant source mechanism at the site?*
- 2) *What is the effect of an intensive pump-and-treat system on the lifetime of the source?*

Dominant Source Mechanism

Two source mechanisms that have the potential to be active at the Sauget site are: 1) *leaching* of unsaturated source materials, and 2) residual Dense Nonaqueous Phase Liquid (DNAPL) *dissolution* (see Figure 1). Six general indicators were evaluated to assess which of these two source mechanisms are primarily responsible for the observed plumes associated with Site I.

The analysis indicated that *DNAPL dissolution* is a major source mechanism at Site I based on an analysis of six different indicators. The following indicators support the conclusion that trapped residual DNAPL is present: dissolved constituent concentrations increase with depth, site constituents extend from the water table to the bottom of the water-bearing interval, and three constituents are found at concentrations that suggest the possible presence of non-mobile residual DNAPL. Some leaching of unsaturated waste/soil materials may also be occurring, as some constituents did not show increasing concentrations with depth. Overall, however, **DNAPL dissolution** appears to be the dominant source mechanism at Site I.

Source Conceptual Model

If DNAPL dissolution is the dominant source mechanism at Site I, it is likely that the DNAPL in the unconsolidated valley fill deposits is present as thin vertical fingers and small horizontal pools throughout the entire vertical extent of the water-bearing unit. Only a small fraction of the total DNAPL mass can ever be removed by pumping any "free-phase" DNAPL pools, if they are found. The rest of the DNAPL is immobile, and will serve as a long-term continuing source of constituents to groundwater.

The current natural mass removal rate via dissolution from the Site I source zone was estimated to be 7000 kg/yr assuming uniform source concentrations throughout the source zone.

Effect of Pumping

As shown by DNAPL dissolution expressions, increasing the flow rate through a DNAPL source zone will significantly decrease the concentration of constituents in

May 21, 2001



the extracted groundwater. For example, if the flowrate through a DNAPL source zone is increased by a factor of 8.9 (to 1500 gpm) due to intensive pumping, the resulting concentration is likely to decrease by a factor of 3.6 while pumping is active, resulting in an overall increase in the mass removal rate of only 2.5 times. Therefore, an intensive pump-and-treat system at Site I with 8.9 times the natural flowrate through the source area (an achievable pumping rate if there is no reinjection) would result in an initial mass removal rate of 17,500 kg/yr.

A planning level source lifetime calculation was done to estimate the relative performance of various remediation schemes. This analysis, while not providing high-confidence estimates of the absolute time to cleanup, does indicate that with an assumed mass of 410,000 kg of VOCs + SVOCs in the saturated zone below Site I, intensive pumping over a 10 to 30 year period does not appear to have an appreciable effect on overall source lifetime (i.e., $\leq 10\%$ reduction). Similar limitations are expected for Sites G/H/L as well.

May 21, 2001



INTRODUCTION

As requested by Solutia Inc. (Solutia), Groundwater Services, Inc. (GSI), has completed a study of hydrogeologic, source, and fate and transport data from the Sauget Area 1 located in Sauget and Cahokia, Illinois. The study was conducted to: 1) help determine what type of source mechanisms are responsible for dissolved constituents found in the affected groundwater, and 2) determine the feasibility of remediating this source area by aggressive pumping. This letter report summarizes the results of the study.

PROJECT BACKGROUND

An extensive RI/FS study of Sauget Area 1 is now being conducted by Solutia. Data from two groundwater monitoring well transects indicates the presence of dissolved constituents migrating west in groundwater from the vicinity of one of the six source areas in Area 1 (i.e., Site I) at concentrations exceeding Illinois Class II groundwater standards.

Source Site I

Site I originally was a sand and gravel pit which received industrial and municipal wastes from 1931 to 1957. Site I is approximately 19 acres in area and underlies a large, fenced, controlled-access, gravel covered truck parking lot and the Sauget City Hall and associated parking lots (Sauget Area 1 EE/CA and RI/FS Support Sampling Plan). Soil samples collected from Site I have indicated elevated levels of volatile organic compounds (e.g., benzene, chlorobenzene); semi-volatile organic compounds (e.g., naphthalene, trichlorobenzene); pesticides; herbicides; PCBs; and metals.

Hydrogeology

Sauget Area 1 is located in the Mississippi River floodplain in an area referred to as the American Bottoms. The geology of the area is described as consisting of unconsolidated valley fill deposits (Cahokia Alluvium) overlying glacial outwash material (Henry Formation). In general, the permeability of the unconsolidated material increases with depth, with the outwash material being comprised of medium- to coarse-grained sand and gravel. The hydrogeologic conceptual model divides the unconsolidated water-bearing unit into three horizons: the shallow horizon (generally 15-30 ft deep), the middle horizon (generally 30-70 ft deep), and the deep horizon (generally 70-110 ft deep).

These unconsolidated deposits are underlain by limestone and dolomite bedrock.

May 21, 2001



Study Constituents

For this study, two classes of constituents were evaluated. The two constituent classes were selected based on prevalence and concentration in groundwater, and include:

- Volatile Organic Compounds (chlorinated and non-chlorinated), and
- Semi-Volatile Organic Compounds (chlorinated and non-chlorinated).

SOURCE MECHANISMS

Knowledge of which source mechanisms are active at a site is important for developing an accurate conceptual model of constituent fate and transport, and for developing appropriate remedial responses. Two source mechanisms that have the potential to be active at the Sauget site are leaching of unsaturated source materials and residual DNAPL dissolution (see Figure 1).

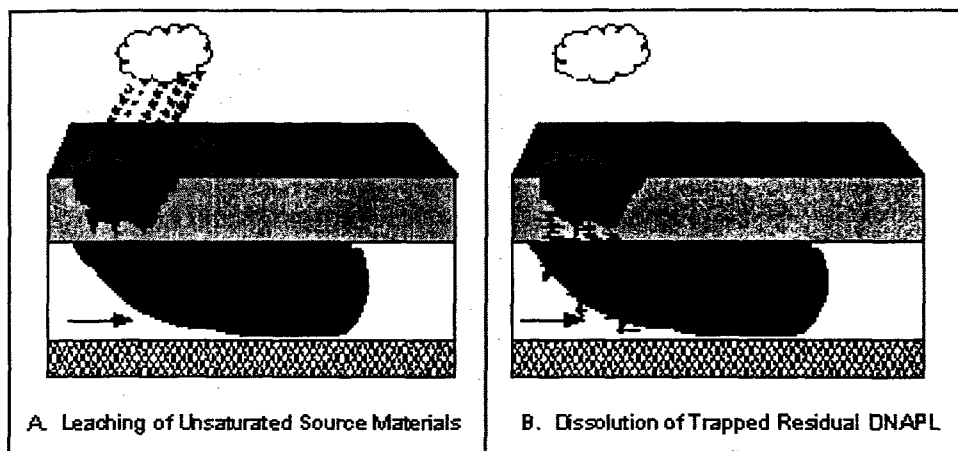


FIGURE 1. Two Potential Groundwater Source Mechanisms

Leaching of unsaturated source materials (see Panel A in Figure 1) results from infiltration of rainfall through near-surface source materials such as waste materials in the source areas and contaminated unsaturated soils. Residual DNAPL dissolution (see Panel B in Figure 1) occurs when soluble organic constituents dissolve from trapped residual DNAPL fingers and pools that entered the subsurface when the source area was active.

May 21, 2001



EVIDENCE OF SOURCE MECHANISMS

The available groundwater data were evaluated to help assess the likelihood that the two most likely source mechanisms are present at the site. The following six indicators were used:

General Indicators of Strong DNAPL Dissolution Processes:

- Indicator 1: Concentrations are generally increasing with depth.
- Indicator 2: Constituents are found deep in the water-bearing unit.
- Indicator 3: Concentrations are above 1% of the pure-phase solubility.
- Indicator 4: Results of EPA Quick Reference Fact Sheet "Estimating Potential for Occurrence of DNAPL at Superfund Sites," (Newell and Ross, 1992).

General Indicators of Strong Soil Leaching Processes:

- Indicator 5: Leachate concentrations (as indicated from TCLP tests of unsaturated waste materials) are greater than groundwater concentrations in the shallow horizon.
- Indicator 6: Concentrations in the shallowest horizon are greater than in deeper horizons.

To assess these indicators, groundwater constituent data were compiled (see Tables 1-2). Data from the groundwater transect (well AA-I-S1 for Site I) were used to evaluate constituent concentrations in the shallow horizon (< 30 ft deep) vs. middle horizon (30-70 ft deep) vs. deep horizon (70-110 ft deep) (see Table 1). Note that only the transect monitoring well closest to the source area was evaluated.

RESULTS

Indicator 1: An evaluation of groundwater data for Site I shows that the sum of *maximum* detectable VOCs + SVOCs in groundwater concentrations from the deep horizon is 47.5 mg/L, compared to only 22.1 mg/L in the shallow horizon (see Table 1). This trend is also seen in the majority of the individual VOC and SVOC constituents. For example, the maximum chlorobenzene concentration increases from 8.7 mg/L in the shallow horizon, to 20 mg/L in the middle horizon, and to 34 mg/L in the deep horizon. Of the five constituents with maximum concentrations greater than 1 mg/L, three (chlorobenzene, 1,2,4-trichlorobenzene, and 1,4-dichlorobenzene) have their maximum concentrations in the middle or deep horizon. The other two, *cis/trans* 1,2-dichloroethene and 4-chloroaniline, have the maximum concentration in the shallow horizon.

Indicator 2: Site constituents are found throughout the entire depth of the unconsolidated unit, from the water table surface to locations over 100 ft deep.

May 21, 2001



Indicator 3: Three site constituents (chlorobenzene, 1,4 dichlorobenzene, and fluoranthene) are found in concentrations that exceed 1% of each respective pure-phase solubility (see Table 1).

Indicator 4: Based on site historical data and observed groundwater concentrations, the EPA Fact Sheet "Estimating Potential for Occurrence of DNAPL at Superfund Sites," shows a "**High-Moderate**" Potential for DNAPL at Site I.

Indicator 5: Of the six constituents where a comparison could be made, five had higher concentrations in the groundwater than in the leachate from waste materials, suggesting that leaching was not responsible for the highest groundwater concentrations at Site I (see Table 2).

Indicator 6: As described above, only two of the five constituents with concentrations greater than 1 mg/L (cis/trans 1,2-dichloroethene and 4-chloroaniline) have their maximum concentrations in the shallow horizon.

KEY POINT: SITE I SOURCE MECHANISMS

DNAPL dissolution is a major source mechanism at Site I based on an analysis of the evaluated indicators. Dissolved constituent concentrations increase with depth, site constituents extend from the water table to the bottom of the water-bearing interval, and three constituents are found at concentrations that suggest the possible presence of non-mobile residual DNAPL.

Some leaching of unsaturated waste/soil materials may also be occurring, as some constituents such as 4-chloroaniline did not show increasing concentrations with depth. Overall, however, DNAPL dissolution appears to be the dominant source mechanism at Site I.

POTENTIAL FOR SOURCE REMEDIATION

Conceptual Model of Source

The following discussion summarizes our conceptual model of the DNAPL source located in the saturated zone beneath Site I:

- DNAPL is present as "fingers" and "pools" in the saturated zone extending from approximately 15 to 110 ft below the surface (see Figure 2 for a conceptual figure).

Supporting Information: "Once penetration of the capillary fringe occurs, downward movement will continue until all the CHC (chlorinated hydrocarbon) solvent is present as suspended fingers (ganglia) in the porous media and/or as pools of CHC perched on low-permeability zones. Once a pool starts to form on top of a low-permeability layer somewhere above the bottom of the aquifer, a continued supply of CHC will cause (1) enlargement of the pool, (2) penetration of the layer, and/or (3) spawning of new downward-moving fingers at the perimeter of the layer." Johnson and Pankow (1992)

May 21, 2001

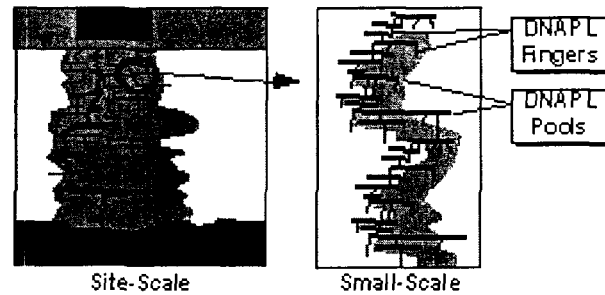


FIGURE 2. Conceptual Model of DNAPL Source Zone

- Small horizontal pools of DNAPL are present throughout the entire vertical extent of the saturated zone, and not just at the bottom of the unit.

Supporting Information: "In granular aquifers, small horizontal zones of residual or free-phase DNAPL need not be caused by particularly low permeability zones such as silt or clay. A minor contrast in grain size distribution and hence permeability, as from a coarse sand layer to a fine sand, causes variation in DNAPL entry pressure. A DNAPL will accumulate on the finer-grained layer while spreading laterally until it reaches the edge of the layer, or until the height of the free-product accumulation on the layer exceeds the entry pressure for the layer." Pankow and Cherry (1996)

- Much or most of the DNAPL mass is present in the trapped residual state that cannot be recovered by pumping.

Supporting Information: "Note that after the continuous NAPL body has been converted to a residual form, the individual NAPL blobs are held very tightly in the porous media by capillary forces. Wilson and Conrad (1984) evaluated the force required to mobilize and completely sweep away residual blobs in porous media in terms of the hydraulic gradient a pumping system would have to generate to either 1) begin blob mobilization, or 2) mobilize all blobs in a porous medium. This relationship, presented as a graph of hydraulic conductivity vs. required hydraulic gradient, indicates that mobilization of NAPL blobs by pumping will occur only in very coarse porous media with a very high hydraulic gradient. The rest of the blobs will stay trapped in the porous media, serving as a long-term source of dissolved contaminants." (Wiedemeier et al., 1999)

(Note: For the unconsolidated alluvial fill deposits at this site, Wilson and Conrad's analysis indicates that a gradient of 0.5 ft/ft would be required to begin to mobilize NAPL blobs. This is 500 times the current hydraulic gradient, and impossible to effect over the entire source area without extensive pumping and re-injection).

- It is extremely unlikely that any DNAPL that may be present at the site is still mobile or will become mobile under current conditions.

Supporting Information: "Once the release of DNAPL into the subsurface ceases, subsurface movement of DNAPL also ceases soon thereafter, perhaps within weeks or months at

May 21, 2001



GROUNDWATER
SERVICES, INC.

solvent sites. The resulting immobile DNAPL then exists in the DNAPL source zone as "residual" non-aqueous liquid and also possibly as "free-product" accumulations ponded on lower permeability layers within aquifers, or on the tops of aquitards. The free-product DNAPL will not become mobile again unless a release of more DNAPL causes further accumulation in the same zones, or unless there are changes in pressure in the surrounding water phase due to groundwater pumping or injection." Pankow and Cherry (1996)

- The presence of pools that can be pumped is relatively rare at DNAPL sites, and if such pools are found and pumped, only a small fraction of the total DNAPL in place is removed.

Supporting Information: "In field investigations of sites where extensive solvent contamination exists, pools of free-product solvent are only rarely found, even when their existence is not in doubt." "It is the author's experience that chlorinated solvents with their high densities form thick pools only rarely." Pankow and Cherry (1996)

"Therefore, in a practical sense, NAPL removal translates to recovery of a small percentage of NAPL at a site (i.e., whatever continuous NAPL can be collected)." Wiedemeier et al., (1999)

- The presence of DNAPL pools and fingers will only occupy a small fraction of the available pore space in the source zone.

Supporting Information: "However, heterogeneity has a marked influence on the direction of DNAPL migration. A random distribution of permeability and displacement pressure will result in a highly erratic pattern of DNAPL flow..." "The remarkable sensitivity of DNAPL penetration to the capillary-hydraulic properties can be expected to result in highly complex, seemingly chaotic saturation distributions in the subsurface." "Even in the idealized case of a perfectly homogeneous medium, DNAPL can be expected to penetrate in the form of narrow, elongated distributions in which the mean saturation of DNAPL is small." Pankow and Cherry (1996)

- The source will persist for a long time.

Supporting Information: "These calculations suggest that zones of residual DNAPL and especially pool DNAPL can persist in the subsurface and contribute to groundwater contamination for decades to centuries." "For most chlorinated solvents, the rate of dissolution of pools will be sufficiently slow that the DNAPL source zones will cause significant contamination of the groundwater for centuries or more." Pankow and Cherry (1996)

- Pumping can increase the rate that mass is removed from the source, but the removal efficiency will be much less than the removal efficiency for natural attenuation.

Supporting Information: "However, the increase in mass removal (by pumping) will not be in proportion to the increase in the groundwater pumping rate because of limitations on the DNAPL dissolution kinetics, and because of further dilution with clean water from outside the source zone." Pankow and Cherry (1996)

May 21, 2001



KEY POINT: CONCEPTUAL MODEL FOR SOURCE

Most of the Site I DNAPL in the unconsolidated valley fill deposits is present as thin vertical fingers and small horizontal pools throughout the entire vertical extent of the water-bearing unit. Only a small fraction of the total DNAPL mass can ever be removed by pumping free-phase pools, if they are found. Under current conditions, the rest of the DNAPL is immobile, and will serve as a long-term continuing source of constituents to groundwater.

ESTIMATED NATURAL DISSOLUTION RATE

Natural Groundwater Flushing Rate

Separate hydraulic conductivity and hydraulic gradient data were developed for the shallow, middle, and deep horizons of the unconsolidated deposits.

The hydraulic conductivity estimates developed for the model were based on: 1) literature reports, and 2) preliminary analysis of RI/FS slug test data. The literature reference (Ritchey and Schicht, 1982) reported that the hydraulic conductivity for the unconsolidated material used for water supply in the American Bottoms area ranged from 5×10^{-2} to 1.4×10^{-1} cm/sec.

The analysis of RI/FS slug test data from Site I wells showed the following hydraulic conductivities:

Horizon	Site I (well ST-I-S) (cm/sec)
Shallow	4.5×10^{-3}
Middle	5.1×10^{-2}
Deep	1.3×10^{-1}

Using the data from the literature report, slug test results, and calibration work, the following hydraulic conductivities were used in the model:

Shallow Horizon:	1×10^{-2} cm/sec
Middle Horizon:	1×10^{-1} cm/sec
Deep Horizon:	1×10^{-1} cm/sec

Using RI/FS potentiometric surface maps provided by Roux Associates, Inc., the following hydraulic gradients were used in the model:

Shallow Horizon:	0.001 ft/ft
Middle Horizon:	0.001 ft/ft
Deep Horizon:	0.001 ft/ft

May 21, 2001



These values yield the following representative values for groundwater Darcy velocity at the site:

Shallow Horizon:	10.4 ft/yr
Middle Horizon:	104 ft/yr
Deep Horizon:	104 ft/yr

As shown by the data, the shallow horizon of the unconsolidated deposits is less permeable, and has a much lower groundwater velocity than the more coarse-grained middle and deep horizons.

The hydrogeologic conceptual model divides the unconsolidated water-bearing unit into three horizons: the shallow horizon (generally 15-30 ft deep), the middle horizon (generally 30-70 ft deep), and the deep horizon (generally 70-110 ft deep). Therefore the assumed saturated thicknesses for the shallow, middle, and deep units were: 15 ft, 40 ft, and 40 ft, respectively. When a 1400 ft wide source zone is assumed (the width of Site I perpendicular to groundwater flow), a naturally-occurring groundwater flushing rate of 168 gpm is obtained (3.1 gpm for the shallow unit, 82.5 gpm for the middle unit, and 82.5 gpm for the deep unit).

Natural Mass Removal Rate

The average total VOC + SVOC concentrations from the transect well closest to Site I (well AA-I-S1) are 13.3 mg/L, 21.9 mg/L, and 19.9 mg/L for the shallow, middle, and deep horizons, respectively. For this planning-level calculation, it was assumed that these concentrations extended throughout the entire width of the Site I source zone, a potential overestimation (however, if all other source removal calculations use the same assumptions, the relative results will be accurate). Therefore, the mass removal rate under natural conditions was estimated by multiplying average VOC + SVOC concentrations for each horizon by the flow for each horizon, and converting to a mass rate of kg/yr leaving the source zone (3.78 L/gal; 1440 min/day; 365 day/yr; 10^{-6} kg/mg). This calculation resulted in the following naturally-occurring mass removal rate totaling approximately 7000 kg/yr from all three horizons:

Shallow Horizon:	82 kg/yr
Middle Horizon:	3,613 kg/yr
<u>Deep Horizon:</u>	<u>3,271 kg/yr</u>
TOTAL:	6,966 kg/yr

KEY POINT: NATURAL MASS REMOVAL RATE

The natural mass removal rate from the Site I source zone is estimated to be 7000 kg/yr assuming uniform source concentrations throughout the source zone.

May 21, 2001



Assumed Flowrate From An Intensive Pump-and-Treat System

Three methods were evaluated to provide a planning-level estimate of the flowrate from an intensive pump-and-treat system at Site I (see Appendix A). First, an empirical well yield relationship (Driscoll, 1986) based on transmissivity, expected drawdown, and assumptions for other variables in the nonequilibrium (Jacob) equation was used. The second method was based on typical well yields from regional water supply wells as reported by Schicht (1965):

"It is a general practice of industries and municipalities to place a well in operation and pump it at high rates, often about 1000 gpm."

The third method was based on evaluating specific capacity (well yield divided by drawdown) provided by Schicht (1965).

These calculation approaches suggest that an intensive pumping system for Site I could yield 1000–2500 gpm. For the purpose of this project, a value of 1500 gpm was used.

KEY POINT: GROUNDWATER FLOWRATE FROM INTENSIVE PUMPING

An intensive pump-and-treat system was assumed to have a yield of 1500 gpm.

EFFECT OF PUMPING GROUNDWATER

Because most of the DNAPL is trapped and cannot be removed by direct pumping, a groundwater pump-and-treat system will generally not remove DNAPL directly, but instead will slowly dissolve the DNAPL trapped in fingers and pools. While this dissolution process is relatively slow and inefficient, it will remove DNAPL mass.

Dissolution Kinetics for DNAPL Fingers and Pools

Several analyses have been performed to evaluate the effect of increased pumping rates on the DNAPL dissolution rate for both fingers and pools. In a key paper written by Hunt et al. in 1988, the authors developed relationships for the kinetics of dissolution in NAPL source zones. They evaluated laboratory studies and mass transfer approaches used in the chemical engineering literature, and derived dissolution expressions for residual NAPL ganglia (also called "fingers" or "blobs"). They concluded that:

"Ganglion lifetimes are weakly dependent on flow velocity such that to decrease the lifetime from 100 years to 10 years requires a three order of magnitude increase (x1000) in flow velocity."

May 21, 2001



In other words, increasing the groundwater pumping rate will increase the finger dissolution rate, but only slightly based on this relationship:

$$\frac{\text{mass transfer rate with pumping}}{\text{mass transfer rate without pumping}} = 10^{\frac{\log_{10} \left[\frac{Q_{\text{pumping}}}{Q_{\text{natural}}} \right]}{3}}$$

Using this NAPL dissolution relationships reported by Hunt et al. (1988), a 1500 gpm pumping system (a 8.9 times increase in the natural flow rate through the system) would result in a 8.9 fold *increase* in water flushed through the system, but a 4.3 fold *decrease* in effluent concentrations, resulting in a net increase in mass removed only by a factor of 2.1:

$$\frac{\text{mass transfer rate with pumping}}{\text{mass transfer rate without pumping}} = 10^{\frac{\log_{10} \left[\frac{1500 \text{ gpm}}{168 \text{ gpm}} \right]}{3}} = 2.1$$

The same type of concentration reduction is expected when higher groundwater flowrates are used to dissolve NAPL pools. Dissolution kinetic relationships developed by Johnson and Pankow (1992) indicate that the mass transfer rate (and pool lifetime) changes with the square root of groundwater velocity:

$$\text{Pool Dissolution Time (yrs)} = 2.43 \times 10^{-5} \rho C_{\text{sat}} [l_p^3 / D_v v_d]^{0.5}$$

where:

- ρ = DNAPL density (g/m³)
- C_{sat} = saturation concentration (g/m³)
- l_p = length of pool in direction of groundwater flow (m)
- D_v = vertical dispersion coefficient (m²/s)
- v_d = Darcy velocity for groundwater (m/day)

Therefore, increasing the groundwater flowrate over a pool by a factor of 8.9 would result in an initial concentration *decrease* by a factor of 3.0 (approximately the square root of 8.9), and the overall *increase* in the mass removal rate by only a factor of 3.0.

Note that these theoretical expressions are supported by lab and field data (e.g., see Pankow and Cherry, 1996). Because source zones include a mixture of pools and fingers, it was assumed in this study that increasing the groundwater flowrate through the source zone by a factor of 8.9 (by pumping) would increase the mass transfer by a factor of 2.5 (the mid-point of finger value of 2.1 and pool values 3.0) when pumping was started. This is because groundwater concentrations decrease by a factor of 3.6 due to mass transfer effects. Note that after pumping is stopped, the concentrations would rebound and increase by a factor by the same amount (in the case of these calculations, by a factor of 3.6).

May 21, 2001



GROUNDWATER
SERVICES, INC.

KEY POINT: EFFECT OF PUMPING GROUNDWATER ON CONCENTRATIONS

As shown by DNAPL dissolution expressions, the mass removal rate from a DNAPL source zone is only weakly dependent on the groundwater pumping rate. For example, if the flowrate through a DNAPL source zone is increased by a factor of 8.9 due to intensive pumping, the mass removal rate will only increase by a factor of 2.5 (a representative value for effects of pumping on DNAPL finger and DNAPL pool dissolution) because concentrations in the recovered groundwater would be reduced by a factor of 3.6 due to mass transfer effects.

Mass Removal Rate of Intensive Pump-and-Treat System

Under an intensive pumping scenario with an increase in natural flow (from 168 gpm to approximately 1500 gpm), the groundwater concentrations being removed from the source are expected to fall to between one-third to one-fifth of the observed concentrations under lower flow, natural conditions. Assuming a middle value of post-pumping concentrations that are 3.6 times smaller than the natural concentrations, the initial VOC + SVOC effluent concentrations from an intensive groundwater pump-and-treat system are estimated to be: 3.7 mg/L, 6.0 mg/L, and 5.5 mg/L for the shallow, middle, and deep units, respectively.

Therefore, under an intensive pump-and-treat scenario where 1500 gpm are being flushed through the Site I source zone (an 8.9-fold increase in the flushing rate), the initial mass removal rate is predicted to only increase by a factor of 2.5, from 7000 kg/yr to 17,500 kg/yr due to mass transfer effects related to DNAPL dissolution. Note that this is only the initial mass removal rate for the intensive pumping case, and that this concentration will drop slowly over time as mass is removed from the system.

KEY POINT: MASS REMOVAL RATE FROM INTENSIVE PUMPING

An intensive pump-and-treat system was estimated to have an initial mass removal rate of 17,500 kg/yr, accounting for both the increased flowrate through the system and decreased concentrations in groundwater.

Effect of Pumping on Source Lifetime

Estimating source longevity is a process involving considerable uncertainty, as the original mass in place, mass removal rate, and the change in the mass removal rate over time must all be known. While absolute estimates have a high level of uncertainty, the relative comparison of remediation alternatives can be made with more confidence. In the analysis below, the absolute values for source lifetime should be considered highly uncertain, while the relative comparisons should be considered more accurate.

May 21, 2001



Estimated Source Mass

A range of estimates of source mass were developed, assuming that the entire saturated zone below Site I is affected by DNAPL. Then the calculated mass removal rates for natural attenuation and an intensive pump-and-treat system were used to estimate source longevity.

Source mass is a function of source volume, the porosity, the residual saturation of DNAPL in the source zone, and the fraction of source volume containing DNAPL. At Site I, the estimated source volume is 1400 ft by 95 ft by 500 ft, or 66,500,000 ft³. Residual saturation (the fraction of open pore space occupied by DNAPL) values are typically assumed to be between 0.01 and 0.15 (see Pankow and Cherry, 1996), and a value of 0.05 was used for this analysis. A porosity of 0.35 was considered representative of the unconsolidated alluvial deposits at the site. Finally, it was assumed that 1% of the aquifer volume contains residual DNAPL.

Based on these assumptions, a planning-level estimate for the volume of DNAPL under Site I was estimated to be 87,000 gallons. Assuming an average density of 1.25 (based on an average of the density of chlorobenzene and 1,4-dichlorobenzene, two of the most commonly-found site constituents), the estimated mass of DNAPL is approximately 410,000 kg. Note that the actual mass may be more or less, but for the purpose of performing relative calculations of source longevity this value appeared to provide reasonable results.

KEY POINT: SITE I SOURCE MASS ESTIMATE

A planning-level source mass estimate of 410,000 kg of VOCs+SVOCs was estimated for the DNAPL source zone below Site I. There is considerable uncertainty in this estimate, with the actual mass potentially being higher or lower than 410,000 kg.

Source Decay Model

A simple source model, originally developed as part of the BIOSCREEN model (Newell et. al. 1996, EPA/600/R-96/087) and now being included as part of the BIOCHLOR model (Aziz et al., 2000, EPA/600/R-00/008) was used to estimate the lifetime of the groundwater source at Site I under different remediation options.

In this simple box model, the source zone is considered to be located in a box containing some mass of dissolvable contaminants. The rate at which contaminants leave the box is estimated from the rate at which flowing groundwater removes contaminants from the box. The time required to achieve a cleanup standard can then be estimated by comparing the mass of contaminants in the box vs. the time required to remove contaminants from the

May 21, 2001



box. To more closely match real-site conditions, the source concentration is assumed to decay over time, in proportion to the remaining source mass (Wiedemeier et al., 1999). With this assumption, the source concentration over time can be described using:

$$C_t = C_{so} \exp^{-k_s t}$$

where:

- C_t = Source concentration at time t (mg/L)
- C_{so} = Observed source concentration at $t = 0$ (mg/L)
- t = Time (years)
- k_s = Source decay coefficient (1/year)

(Note that this decay coefficient **is not** related in any way to first-order decay coefficients reported in the literature for natural attenuation, as the literature values typically represent decay half-lives from 0.1 to 10 years and represent biodegradation of dissolved contaminants in the plume *once they have left the source*. The source decay coefficient values represent how quickly a source zone is being depleted, and will usually have much longer half-lives, typically tens or hundreds of years.)

The source decay coefficient, representing how quickly the source is being depleted, can be derived using estimates of the source mass and rate that contaminants leave the source (Newell et al., 1996):

$$k_s = \frac{Q \cdot C_{so}}{M_o}$$

where:

- Q = Groundwater flowrate through source zone (L/year)
- C_{so} = Observed source concentration at time = 0 (mg/L)(or kg/L)
- M_o = Dissolvable mass in source at time = 0 (mg)(or kg)

This model assumes that the only mass leaving the source zone is dissolved in the water flowing through the source zone. Note that Q and C_{so} are related; the thickness of the source zone should be matched with an appropriate average concentration for that entire depth horizon.

With a first-order source decay term, the source concentration at any time can be derived, providing the time required to reach any concentration:

$$t = -\frac{1}{k_s} \ln \left(\frac{C_t}{C_{so}} \right)$$

May 21, 2001



where:

t = Time required to reach concentration C_t (years)

Five Source Lifetime Cases

For this analysis, five different cases were evaluated using the source lifetime described above:

- Case 1: Natural attenuation only (initial removal rate of 7000 kg/yr)
- Case 2: 1 year of intensive pump-and-treat (initial removal rate of 17,500 kg/yr), followed by natural attenuation
- Case 3: 5 years of intensive pump-and-treat (initial removal rate of 17,500 kg/yr), followed by natural attenuation
- Case 4: 10 years of intensive pump-and-treat (initial removal rate of 17,500 kg/yr), followed by natural attenuation
- Case 5: 30 years of intensive pump-and-treat (initial removal rate of 17,500 kg/yr), followed by natural attenuation

With this approach (see Appendix B), the following times to cleanup were estimated:

		Estimated Time to Cleanup (years)	% Reduction from Natural Attenuation Only
Case 1	Natural Attenuation Only	488	-
Case 2	1 Yr of Intensive Pump-and-Treat + Natural Attenuation	486	0.4% reduction
Case 3	5 Yrs of Intensive Pump-and-Treat + Natural Attenuation	480	2% reduction
Case 4	10 Yrs of Intensive Pump-and-Treat + Natural Attenuation	472	3% reduction
Case 5	30 Yrs of Intensive Pump-and-Treat + Natural Attenuation	441	10% reduction

Figure 3 shows a comparison of source concentrations vs. time for two of the six cases.

May 21, 2001



Source Concentration vs. Time Analysis Sauget Area 1, Site I

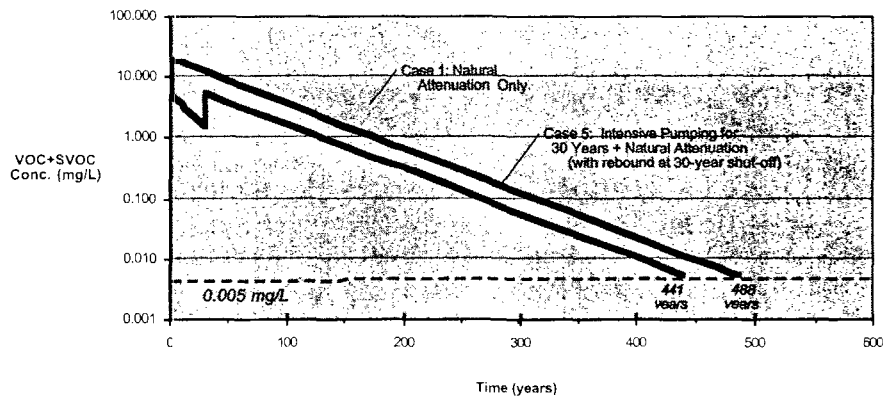


FIGURE 3. Source concentration vs. time graphs for Case 1 (Natural Attenuation Only) and Case 5 (30 Years of Intensive Pump-and-Treat + Natural Attenuation). For Case 1, concentrations start at 20 mg/L and decline as a first order decay relationship over time. For Case 5, the source concentration starts at 20 mg/L, but concentrations are reduced by a factor of 3.6 due to mass transfer effects caused by the almost 9 times increase in groundwater flow through the source zone. After 30 years, pumping is stopped, groundwater flow is restored to natural conditions, and mass transfer effects cause an increase in concentration by a factor of 3.6 (the "rebound" effect). Overall, the source modeling exercise shows that with the source assumptions described in the text, the time required to restore groundwater is reduced only slightly by 30 years of intensive pumping, from 488 years to 441 years (10% reduction).

Sensitivity Analysis

The source lifetime analysis has several areas of uncertainty, and should be used to evaluate relative differences between remediation alternatives rather than to provide an absolute source lifetime estimate. Significant sources of uncertainty include:

- *The assumption that concentrations observed in well AA-I-S1 extend throughout the entire 1400 ft source width of Site I.* If some sections of the 1400 ft source width of Site I are lower concentration, the following impact on the source lifetime is expected: 1) for the natural attenuation case, the overall source lifetime estimates will not change as both the removal rate and the mass in the source are functions of the source width; and 2) for the pumping case, some reduction in overall source lifetime is expected as source mass is dependent on source width but removal rate is not (it is dependent on pumping rate and expected concentrations).

May 21, 2001



- *The assumptions that the source is represented by a residual DNAPL saturation of 0.05 and that 1% of the source zone is impacted by DNAPL residual. These assumptions have a great deal of uncertainty (the literature reports that residual saturations can be as high as 0.50), and were selected in part to yield source lifetimes in the range of several hundreds of years to match the source conceptual model discussed above. If the source is much smaller than the estimated 410,000 kg of VOCs+SVOCs, then the impact of a pumping system will be greater, and greater than a 1% to 10% reduction in source lifetime will be realized. If the source mass is only 41,000 kg (an unlikely event based on the persistence of the source to date), then an intensive pump-and-treat system is predicted to reduce the source lifetime by from 49 years (natural attenuation alone) to 22 years (intensive pumping). Conversely, if the mass is greater, a pump-and-treat system will have less of an effect.*

Other, potentially less significant sources of uncertainty are:

- *The assumption that concentrations under a pumping scenario will be smaller than concentrations observed under natural flow conditions. While there is uncertainty in the actual amount, it has been demonstrated in lab studies and the field that increasing the flowrate through a DNAPL source zone will result in lowered concentrations (for example, see Pankow and Cherry, 1996). Therefore we expect some concentration reduction with a pump-and-treat scenario.*
- *The assumption that the flow throughout each interval is uniform and that the concentration in each interval can be calculated by averaging each sample point. These assumptions were used in the mass removal calculation. While there may be some uncertainty in these assumptions, the large number of vertical samples reduces the potential error.*
- *The assumption of a first-order decay relationship for the source dissolution rate. This assumption is based on observations about source decay, and is now used in two EPA peer-reviewed models, BIOSCREEN and BIOCHLOR. While the exact source concentrations curve may not be exactly first order, it will almost certainly fit a first-order decay curve better than assuming constant source concentrations until the source is exhausted. (Note that the use of the first order decay model for the source does not mean that literature-based first-order decay constants for dissolved constituents were used. A source decay constant is based on removal rate and initial source mass, while a biodegradation rate is based on how fast concentrations decay after they leave the source. This study used a source decay approach, and did not use biodegradation rates to estimate source lifetime).*
- *No availability effects related to desorption of constituents at low concentrations have been considered. Slow desorption of non-available fraction of constituents sorbed to aquifer materials will likely reduce the efficiency of any flushing*

May 21, 2001



technology. More pronounced effects may be observed for intensive pumping scenarios.

Additional Analysis

A similar analysis was performed for Sites G/H/L using the same calculation approach as was used for Site I (Appendix B). Two cases were performed, and show little impact from a five-year intensive pumping program:

		Estimated Time to Cleanup (years)	% Reduction from Natural Attenuation Only
Case 6	Natural Attenuation Only – Sites G/H/L	434	-
Case 7	5 Yrs of Intensive Pump-and-Treat + Natural Attenuation	427	2% reduction

An evaluation of other constituents present in Sites G/H/I/L groundwater, such as herbicides, pesticides, dioxins, and metals indicates that some constituents will like achieve cleanup goals faster than the VOCs + SVOCs analyzed for this source report, and others may take longer. Ratios of the maximum observed concentrations at Area 1 vs. the Illinois Class I standard for representative constituents provide a general indication of how quickly various constituents may achieve cleanup goals:

CONSTITUENT (Constituent Class)	MAXIMUM CONCENTRATION IN GROUNDWATER (ug/L)	ILLINOIS CLASS I STANDARD (ug/L)	RATIO OF MAX. CONC. / ILLINOIS CLASS I STD.
Chlorobenzene (VOC)	34,000	100	340
2,4-dichlorobenzene (SVOC)	14,000	75	187
Alpha-BHC (Herbicide)	72	0.03	2400
2,4-D (Pesticide)	190	70	2.7
Total PCBs (PCB)	12	0.5	24
Cu (Metal)	3000	650	4.6
Ni (Metal)	7800	100	78
Pb (Metal)	3600	7.5	480

May 21, 2001



Zn (Metal)	33,000	5000	6.6
------------	--------	------	-----

On the basis of this general evaluation, alpha-BHC may take longer to achieve cleanup goals than the VOCs+SVOCs, while 2,4-D may take less time. Other factors, such as the mass of each constituent in the source zone and the constituent-specific fate and transport process will determine the ultimate time required to remediate the Area 1 source zones.

KEY POINT: ESTIMATED SOURCE LIFETIMES FOR SEVEN CASES

A planning level source lifetime calculation was done to estimate the relative performance of various remediation schemes. This analysis, while not providing high-confidence estimates of the absolute time to cleanup, does indicate that with an assumed mass of 410,000 kg of VOCs + SVOCs in the saturated zone below Site I, intensive pumping over a 1 to 30 year period does not appear to have an appreciable effect on overall source lifetime (i.e., $\leq 10\%$ reduction). Similar limitations are expected at Sites G/H/L as well.

CONCLUSIONS

Based on the overall groundwater source evaluation at Site I of Sauget Area 1, DNAPL dissolution appears to be the dominant source mechanism. Planning level source lifetime calculations indicate that intensive groundwater pumping will not have an appreciable effect on the overall source lifetime at Site I or at Site G/H/L.

May 21, 2001



REFERENCES

- Aziz, C.E., C.J. Newell, J.R. Gonzales, P.E. Haas, T.P. Clement, and Y. Sun, 2000. BIOCHLOR Natural Attenuation Decision Support System, User's Manual Version 1.0, U.S. EPA, Office of Research and Development, www.gsi-net.com, EPA/600/R-00/008, Washington D.C., January, 2000.
- Driscoll, F., 1986. Ground Water and Wells, 2nd Ed., Johnson Division, St. Paul, Minnesota.
- Hunt, J.R., N. Sitar, and K.D. Udell, 1988. "Nonaqueous Phase Liquid Transport and Cleanup", *Water Res. Research*, Vol. 24, No. 8, 1988.
- Johnson, R.L., and J.F. Pankow, 1992. "Dissolution of Dense Chlorinated Solvents in Groundwater, 2. Source Functions for Pools of Solvents", *Environ. Science and Technology*, v. 26, no. 5, p. 896-901.
- Newell, C.J., J. Gonzales, and R. McLeod, 1996. BIOSCREEN Natural Attenuation Decision Support System, Version 1.3, U.S. Environmental Protection Agency, EPA/600/R-96/087, www.epa.gov/ada/kerrlab.html
- Newell, C.J. and R. Ross, 1992. Estimating Potential for Occurrence of DNAPL at Superfund Sites, EPA Quick Reference Fact Sheet (EPA Publication 9355.4-07FS), January 1992.
- Pankow, J. F. and J. A. Cherry, 1996. Dense Chlorinated Solvents and other DNAPLs in Groundwater, Waterloo Press, Waterloo, Ontario, 1996.
- Ritchey, J. D., and R.J. Schicht, 1982. "Ground-Water Management in the American Bottoms, Illinois, State, County, Regional and Municipal Jurisdiction of Ground-Water Protection," Proceedings of the Sixth National Ground-Water Quality Symposium, Atlanta, Georgia, Sept. 22-24, EPA/National Water Well Association, Columbus, Ohio.
- Schicht, R.J., 1965. Ground-Water Development in East St. Louis Area, Illinois, Report of Investigation 51, Illinois State Water Survey, Urbana, Illinois.
- Wiedemeier, T.H., H.S. Rifai, C.J. Newell, and J.T. Wilson, 1999. Natural Attenuation of Fuel Hydrocarbons and Chlorinated Solvents, John Wiley and Sons, New York, New York.
- Wilson, J.L. and S.H. Conrad, 1984. "Is Physical Displacement of Residual Hydrocarbons a Realistic Possibility In Aquifer Restoration?" National Water Well Association, Proceedings of Petroleum Hydrocarbons and Organic Chemicals in Ground Water Conference, Houston, Texas, November 1984.



TABLE 1
 SUMMARY OF SITE 1 GROUNDWATER CONCENTRATIONS BY DEPTH AND
 COMPARISON TO CONSTITUENT SOLUBILITY
 Sampling Period: November to December 1999

Solutia Inc.
 Area 1, Sauget and Cahokia, Illinois

Detected Constituent	0-30 ft Depth Conc. (mg/L)	30-70 ft Depth Conc. (mg/L)	70+ ft Depth Conc. (mg/L)	Solubility (mg/L)
VOCs				
1,1-Dichloroethane	0.96	<0.5	<1.0	5,060
1,1-Dichloroethene	0.032 J	<0.5	<1.0	2,250
Benzene	0.62	0.19	0.14 J	1,750
Chlorobenzene	8.7	20.0	34.0	<u>472</u>
cis/trans-1,2-Dichloroethene	1.2	0.31	0.001 J	3,500 (7)
Ethylbenzene	0.87	0.27	0.074	169
Tetrachloroethene	<0.5	<0.5	0.001 J	200
Toluene	0.018 J	0.086 J	0.00089 J	526
Vinyl Chloride	0.97	0.32	0.0012 J	2,760
Xylenes, total	<0.5	0.023 J	0.014	186
SVOCs				
1,2,4-Trichlorobenzene	<0.01	<0.5	2.7	300
1,2-Dichlorobenzene	0.13	0.32 J	0.5	156
1,3-Dichlorobenzene	0.11	0.29 J	0.150 J	NA
1,4-Dichlorobenzene	4.4	10 D	9.7 D	<u>73.8</u>
2,4,5-Trichlorophenol	<0.01	<0.5	0.0018 J	1,200
2,4-Dichlorophenol	<0.01	0.042	0.047 J	4,500
2-Chlorophenol	0.0055 J	0.039	0.052	22,000
2-Methylnaphthalene	<0.01	<0.5	0.0013 J	NA
2-Methylphenol (o-cresol)	<0.01	0.003 J	<0.4	26,000
4-Chloroaniline	4.1 D	1.7 D	0.018	5,300
Acenaphthene	<0.01	<0.5	0.00033 J	4.24
Carbazole	0.0014 J	0.013	0.013	7.48
Di-n-butylphthalate	<0.01	0.00034 J	0.00051 J	11.2
Dibenzofuran	<0.01	0.019 J	<0.4	NA
Diethylphthalate	<0.01	0.0051 J	<0.4	1,080
Fluoranthene	<0.01	0.022 J	<0.4	<u>0.206</u>
Hexachlorobenzene	<0.01	<0.5	0.001 J	6.2
N-Nitrosodiphenylamine	0.0053	0.028	0.02	35.1
Naphthalene	0.0042 J	0.024	0.066	31
Phenanthrene	<0.01	0.089 J	0.0013 J	NA
Phenol	<0.01	0.0044 J	<0.4	82,800
bis(2-chloroethyl)ether	0.0011 J	<0.5	<0.4	17,200
bis(2-ethylhexyl)phthalate	0.00069 J	<0.09	<0.072	0.34
Total Detected Conc. (mg/L)	22.1	33.8	47.5	

Notes:

- 1) Table includes only those compounds detected in at least one groundwater sample for each constituent class. Comparison to solubility includes groundwater sampled at any depth in source area monitoring well.
- 2) Groundwater samples included are from nearest source area monitoring well only (i.e., AA-I-S1).
- 3) J = Estimated value. D = Diluted sample. NA = Not available.
- 4) **Bold** type denotes maximum groundwater concentration by depth.
- 5) **Underlined bold italics** type denotes maximum groundwater concentration exceeds 1% of constit. solubility.
- 6) Lowest solubility of cis/trans-1,2-Dichloroethene pair indicated.
- 7) Solubility data from Illinois Tiered Approach to Corrective Action Objectives (TACO).
- 8) For comparison purposes, non-detectable concentrations are taken as the detection limit shown.



TABLE 2
 SUMMARY OF SITE I GROUNDWATER CONCENTRATIONS BY DEPTH VERSUS
 TCLP WASTE DATA

Sampling Period: November to December 1999

Solutia Inc.
 Area 1, Sauget and Cahokia, Illinois

Detected Constituent	0-30 ft Depth Conc. (mg/L)	30-70 ft Depth Conc. (mg/L)	70+ ft Depth Conc. (mg/L)	Max. TCLP Conc. (mg/L)	Media With Max. Conc.
VOCs					
1,1-Dichloroethane	0.96	<0.5	<1.0	NA	-
1,1-Dichloroethene	<u>0.032 J</u>	<0.5	<1.0	<0.02	GW
Benzene	<u>0.62</u>	0.19	0.14 J	0.14	GW
Chlorobenzene	8.7	20.0	<u>34.0</u>	8.9	GW
cis/trans-1,2-Dichloroethene	1.2	0.31	0.001 J	NA	-
Ethylbenzene	0.87	0.27	0.074	NA	-
Tetrachloroethene	<0.5	<0.5	0.001 J	0.29	-
Toluene	0.018 J	0.086 J	0.00089 J	NA	-
Vinyl Chloride	<u>0.97</u>	0.32	0.0012 J	<0.04	GW
Xylenes, total	<0.5	0.023 J	0.014	NA	-
SVOCs					
1,2,4-Trichlorobenzene	<0.01	<0.5	2.7	NA	-
1,2-Dichlorobenzene	0.13	0.32 J	0.5	NA	-
1,3-Dichlorobenzene	0.11	0.29 J	0.150 J	NA	-
1,4-Dichlorobenzene	4.4	<u>10 D</u>	9.7 D	1.3	GW
2,4,5-Trichlorophenol	<0.01	<0.5	0.0018 J	<u>1.4</u>	TCLP
2,4-Dichlorophenol	<0.01	0.042	0.047 J	NA	-
2-Chlorophenol	0.0055 J	0.039	0.052	NA	-
2-Methylnaphthalene	<0.01	<0.5	0.0013 J	NA	-
2-Methylphenol (o-cresol)	<0.01	0.003 J	<0.4	0.014 J	-
4-Chloroaniline	4.1 D	1.7 D	0.018	NA	-
Acenaphthene	<0.01	<0.5	0.00033 J	NA	-
Carbazole	0.0014 J	0.013	0.013	NA	-
Di-n-butylphthalate	<0.01	0.00034 J	0.00051 J	NA	-
Dibenzofuran	<0.01	0.019 J	<0.4	NA	-
Diethylphthalate	<0.01	0.0051 J	<0.4	NA	-
Fluoranthene	<0.01	0.022 J	<0.4	NA	-
Hexachlorobenzene	<0.01	<0.5	0.001 J	<0.05	-
N-Nitrosodiphenylamine	0.0053	0.028	0.02	NA	-
Naphthalene	0.0042 J	0.024	0.066	NA	-
Phenanthrene	<0.01	0.089 J	0.0013 J	NA	-
Phenol	<0.01	0.0044 J	<0.4	NA	-
bis(2-chloroethyl)ether	0.0011 J	<0.5	<0.4	NA	-
bis(2-ethylhexyl)phthalate	0.00069 J	<0.09	<0.072	NA	-

GW Conc. Greater 5
 TCLP Conc. Greater 1

Notes:

- 1) Table includes only those compounds detected in at least one groundwater sample for each constituent class.
- 2) Comparison to TCLP waste concentration includes groundwater sampled at any depth in source area monitoring well.
- 3) Groundwater samples included are collected from nearest source area monitoring well only (i.e., AA-I-S1).
- 4) J = Estimated value. D = Diluted sample.
- 5) Underlined bold type denotes maximum groundwater concentration or TCLP concentration.
- 6) TCLP waste data from unsaturated waste samples.
- 7) NA = Not analyzed.
- 7) For comparison purposes, non-detectable concentrations are taken as the detection limit shown.

May 21, 2001



APPENDIX A
DESIGN PUMPING RATE OF HYDRAULIC CONTAINMENT WELLS
Groundwater Alternative D, Intensive Pumping, Sites G, H, I, and L
Sauget Area 1, Sauget and Cahokia, Illinois

PROBLEM: What is estimated pumping rate and number of wells for intensive pumping system for Site I + Sites G/H/L plume?

ASSUMPTIONS:

$K = 0.1$ cm/sec for middle, deep horizon

$b = 80$ ft (40 ft middle horizon, 40 ft deep horizon)

$i = 0.001$ ft/ft

Available drawdown (s) = 15 ft (thickness of shallow unit) (this equals thickness of shallow saturated horizon)

METHOD: Use three different methods to develop a basis for flowrates for an intensive pumping system for the combined Site I + Site G/H/L plume areas.

Method 1. First, an empirical well pumping rate relationship (Driscoll, 1986) based on transmissivity, expected drawdown, and assumptions for other variables in the nonequilibrium (Jacob) equation was used. For this site, a transmissivity of 170,000 gpd/ft was calculated (based on an assumed hydraulic conductivity of 0.1 cm/sec and a saturated thickness of 80 ft for the combined middle and deep horizons).

For unconfined units:

$$\frac{Q}{s} = \frac{T}{1500} \quad (\text{Eqn. 3, } Q \text{ in gpm, } s \text{ in ft, } T \text{ in gpd/ft})$$

$$Q(\text{gpm}) = \frac{\left(T \frac{\text{gpd}}{\text{ft}}\right)(s \text{ ft})}{1500}$$

$$T = (K)(b_T)$$

$$T = \left(0.1 \frac{\text{cm}}{\text{sec}}\right) \left(\frac{86400 \text{ sec}}{\text{day}}\right) \left(\frac{\text{in}}{2.54 \text{ cm}}\right) \left(\frac{\text{ft}}{12 \text{ in}}\right) (80 \text{ ft}) \left(\frac{7.48 \text{ gal}}{\text{ft}^3}\right)$$

$$T = 170,000 \text{ gpd/ft}$$

$$Q(\text{gpm}) = \frac{\left(170,000 \frac{\text{gpd}}{\text{ft}}\right)(15 \text{ ft})}{1500}$$

$$Q = 1700 \text{ gpm}$$

May 21, 2001



so that:

Q = 1700 gpm for pumping from a regional pumping well

Method 2. Schicht (1965) reports that "It is a general practice of industries and municipalities to place a well in operation and pump it at high rates, often about 1000 gpm." Therefore based on this method:

Q = 1000 gpm for pumping from a regional pumping well

Method 3. Schicht also reports the specific capacity from three wells in T2N, R10W (where Area 1 is located) as being 152.5, 188, and 158 gpm/ft, respectively. By averaging these specific capacities (166 gpm/ft), and multiplying by an assumed drawdown of 15 ft, a pumping rate of **2490 gpm** is obtained. As would be expected, use of specific capacities results in a wide range of predicted well pumping rates due to the effects of well construction, well condition, and local hydrogeologic conditions.

Q = 2500 gpm for pumping from a regional pumping well

RESULT: These calculation approaches suggest that a regional pumping well could yield from 1000 to 2500 gpm in the Area 1 location.

Therefore, it was assumed that the total pumping rate of any intensive pumping system would also be in this range, although the flow would be distributed among several wells. Therefore the following conceptual design was developed:

Q_{total} = 1500 gpm total flowrate (based on lower-middle range of flowrate estimates to be conservative)

May 21, 2001



APPENDIX B
RELATIVE SOURCE LIFETIME OF AREA I UNDER NATURAL
ATTENUATION VS. INTENSIVE PUMP AND TREAT
Groundwater Alternative D, Intensive Pumping, Sites G, H, I, and L
Sauget Area 1, Sauget and Cahokia, Illinois

I. SOURCE LIFETIME CALCULATION: SITE I

PROBLEM: What is relative source lifetime of Site I under natural attenuation vs. intensive pump and treat conditions?

ASSUMPTIONS:

1. Source Volume = $(1400\text{ft})(500\text{ft})(95\text{ft})\left(7.48\frac{\text{gal}}{\text{ft}^3}\right)(0.35)(0.05)(0.01) = 87,000\text{ gals}$

$$\text{Source Mass} = (87,000\text{gal})\left(\frac{3.78\text{L}}{\text{gal}}\right)\left(\frac{1.25\text{g}}{\text{L}}\right) = 410,000\text{ kg}$$

Where: width = 1400 ft; length = 500 ft; sat. thickness = 95 ft; porosity = 0.35; assumed residual saturation = 0.05; fraction of source containing residual saturation = 0.01. (see text)

2. Current Mass Removal Rate: 7000 kg/yr (Natural Attenuation) (see text)
Initial Intensive Pumping Removal Rate: 17,500 kg/yr (Intensive Pump-and-Treat) (see text).
3. Case 1 Natural Attenuation Only – Site I
Case 2 1 Yr of Intensive Pump-and-Treat + Natural Attenuation – Site I
Case 3 5 Yrs of Intensive Pump-and-Treat + Natural Attenuation – Site I
Case 4 10 Yrs of Intensive Pump-and-Treat + Natural Attenuation – Site I
Case 5 30 Yrs of Intensive Pump-and-Treat + Natural Attenuation – Site I
4. Starting concentration under natural conditions: 20 mg/L (representative of middle and deep units in 1999). Starting concentration under pumping conditions: 5.5 mg/L (due to mass-transfer effects for deep and middle units; factor of 3.6 reduction).
5. Assumed ending concentration: 0.005 mg/L (MCL for several constituents).

MODEL:

$$\frac{C(t)}{C_{(now)}} = e^{-k_p t} \quad (\text{from BIOSCREEN and BIOCHLOR models; see text})$$

May 21, 2001



$$k_s = \frac{\text{Mass Removal Rate (kg/yr)}}{\text{Mass (kg)}} \quad (k_s = \text{source decay constant})$$

$$t(\text{yr}) = \frac{-\ln\left(\frac{C_t}{C_{\text{now}}}\right)}{k_s}$$

Model Applied to Case 1: Natural Attenuation Only

$$t(\text{yr}) = \frac{-\ln\left(\frac{0.005}{20}\right)}{0.017}$$

RESULT (Case 1): $t = 488 \text{ years}$

Model Applied to Case 2: Intensive Pump and Treat With 1 Year of Pumping

$$k_s = \frac{17,500 \frac{\text{kg}}{\text{yr}}}{410,000 \text{ kg}} = 0.043 \text{ yr}^{-1}$$

$$\frac{C_{1\text{yr}}}{C_{\text{now}}} = e^{-k_s t}$$

$$\frac{C_{1\text{yr}}}{5.5 \text{ mg/L}} = e^{-(0.043 \text{ yr}^{-1})(1 \text{ yr})}$$

$$C_{1 \text{ yr}} = 5.27 \text{ mg/L}$$

Time to cleanup after 1 yr of pumping is finished, with 3.6-times increase in concentration due to rebound ($5.27 \text{ mg/L} \times 3.6 = 19.0 \text{ mg/L}$).

$$\frac{0.005 \text{ mg/L}}{19.0 \text{ mg/L}} = e^{-(0.017 \text{ yr}^{-1})(t_{\text{years}})}$$

$$t = \frac{-\ln\left(\frac{0.005}{19.0}\right)}{0.017}$$

$$t = 485 \text{ years}$$

May 21, 2001



RESULT (Case 2): Total time to cleanup (Intensive Pump-and-Treat for 1 yr) = 1 + 485 = **486 years**

Model Applied to Case 3: Intensive Pump and Treat With 5 Years of Pumping

$$k_s = \frac{17,500 \frac{kg}{yr}}{410,000 kg} = 0.043 yr^{-1}$$

$$\frac{C_{5 yrs}}{C_{now}} = e^{-k_s t}$$

$$\frac{C_{5 yrs}}{5.5 mg/L} = e^{-(0.043 yr^{-1})(5 yrs)}$$

$$C_{5 yrs} = 4.44 mg/L$$

Time to cleanup after 5 yrs of pumping is finished, with 3.6-times increase in concentration due to rebound (4.44 mg/L * 3.6 = 16.0 mg/L).

$$\frac{0.005 mg/L}{16.0 mg/L} = e^{-(0.017 yr^{-1})(t yrs)}$$

$$t = \frac{-\ln\left(\frac{0.005}{16.0}\right)}{0.017}$$

$$t = 475 years$$

RESULT (Case 3): Total time to cleanup (Intensive Pump-and-Treat for 5 yrs) = 5 + 475 = **480 years**

May 21, 2001



Model Applied to Case 4: Intensive Pump and Treat With 10 Years of Pumping

$$k_s = \frac{17,500 \frac{kg}{yr}}{410,000 kg} = 0.043 yr^{-1}$$

$$\frac{C_{10yrs}}{C_{now}} = e^{-k_s t}$$

$$\frac{C_{10yrs}}{5.5 mg/L} = e^{-(0.043 yr^{-1})(10yrs)}$$

$$C_{10yrs} = 3.58 mg/L$$

Time to cleanup after 10 yrs of pumping is finished, with 3.6-times increase in concentration due to rebound ($3.58 mg/L * 3.6 = 12.9 mg/L$).

$$\frac{0.005 mg/L}{12.9 mg/L} = e^{-(0.017 yr^{-1})(t yrs)}$$

$$t = \frac{-\ln\left(\frac{0.005}{12.9}\right)}{0.017}$$

$$t = 462 years$$

RESULT (Case 4): Total time to cleanup (Intensive Pump-and-Treat for 10 yrs) = $10 + 462 = 472$ years

Model Applied to Case 5: Intensive Pump and Treat With 30 Years of Pumping

$$k_s = \frac{17,500 \frac{kg}{yr}}{410,000 kg} = 0.043 yr^{-1}$$

$$\frac{C_{30yrs}}{C_{now}} = e^{-k_s t}$$

$$\frac{C_{30yrs}}{5.5 mg/L} = e^{-(0.043 yr^{-1})(30yrs)}$$

$$C_{30yrs} = 1.51 mg/L$$

Time to cleanup after 30 yrs of pumping is finished, with 3.6-times increase in concentration due to rebound ($1.51 mg/L * 3.6 = 5.4 mg/L$).

May 21, 2001



$$\frac{0.005 \text{ mg/L}}{5.4 \text{ mg/L}} = e^{-(0.017 \text{ yr}^{-1})(t \text{ yrs})}$$

$$t = \frac{-\ln\left(\frac{0.005}{5.4}\right)}{0.017}$$

$$t = 411 \text{ years}$$

RESULT (Case 5): Total time to cleanup (Intensive Pump-and-Treat for 30 yrs) = 30 + 411 = **441 years**

CONCLUSION: Comparison of Cleanup Times – Site I

Case 1	Natural Attenuation Only.....	488 years
Case 2	1 Yr of Intensive Pump-and-Treat + Natural Attenuation.....	486 years
Case 3	5 Yrs of Intensive Pump-and-Treat + Natural Attenuation	480 years
Case 4	10 Yrs of Intensive Pump-and-Treat + Natural Attenuation.....	472 years
Case 5	30 Yrs of Intensive Pump-and-Treat + Natural Attenuation.....	441 years

May 21, 2001



II. SOURCE LIFETIME CALCULATION: SITES G/H/L

PROBLEM: What is relative source lifetime of Sites G/H/L under natural attenuation vs. intensive pump and treat conditions?

ASSUMPTIONS:

1. Assume Sites G/H/L together have approximately same dimensions as Site I, with 1% of the starting mass as Site I, because VOC+SVOC concentrations are much lower leaving Sites G/H/L (~ 0.20 mg/L) than Site I (~ 20 mg/L).
2. Assume ratio of source mass at Sites G/H/L and Site I are proportional to ratio of representative concentrations and width parallel to groundwater flow leaving Sites G/H/L and Site I.

$$\begin{aligned}\text{Source Mass} &= \left(\frac{\text{representative conc. Sites G/H/L mg/L}}{\text{representative conc. Site I mg/L}} \right) (\text{Est. Mass Site I kg}) \\ &= \left(\frac{0.20 \text{ mg/L}}{20 \text{ mg/L}} \right) (410000 \text{ kg}) \\ &= 4100 \text{ kgs}\end{aligned}$$

3. Current Mass Removal Rate: Assume 1% of Site I mass removal rate based on ratio of representative concentration at Site I (20 mg/L VOC+SVOC) to representative concentration at Sites G/H/L (0.20 mg/L VOC+SVOC).

Natural Source Removal Rate =

$$\begin{aligned}&\left(\frac{\text{representative conc. Sites G/H/L mg/L}}{\text{representative conc. Site I mg/L}} \right) \left(\frac{\text{Width Sites G/H/L}}{\text{Width Site I}} \right) (\text{Est. Mass Removal Rate Site I kg/yr}) \\ &= \left(\frac{0.20 \text{ mg/L}}{20 \text{ mg/L}} \right) \left(\frac{750 \text{ ft}}{1400 \text{ ft}} \right) (7000 \text{ kg/yr}) \\ &= 35 \text{ kg/yr}\end{aligned}$$

Use Initial Intensive Pumping Removal Rate of 2.5 times 34 kg/yr (Intensive Pump-and-Treat= 87.5 kg/yr)

4. Run analysis for two cases:
Case 6 Natural Attenuation Only – Site G/H/L
Case 7 5 Yrs of Intensive Pump-and-Treat + Natural Attenuation – Site G/H/L
5. Starting concentration under natural conditions: 0.20 mg/L (representative of middle and deep units in 1999). Starting concentration under pumping conditions: 0.056 mg/L (due to mass-transfer effects for middle and deep units; factor of 3.6 reduction).
6. Assumed ending concentration: 0.005 mg/L (MCL for several constituents).

May 21, 2001



MODEL:

$$\frac{C(t)}{C_{(now)}} = e^{-k_s t} \quad (\text{from BIOSCREEN and BIOCHLOR models; see text})$$

$$k_s = \frac{\text{Mass Removal Rate (kg/yr)}}{\text{Mass (kg)}} \quad (k_s = \text{source decay constant})$$

$$t(\text{yr}) = \frac{-\ln\left(\frac{C_t}{C_{now}}\right)}{k_s}$$

Model Applied to Case 6: Natural Attenuation Only

$$k_s = \frac{35 \frac{\text{kg}}{\text{yr}}}{4100 \text{ kg}} = 0.0085 \text{ yr}^{-1}$$

$$t(\text{yr}) = \frac{-\ln\left(\frac{0.005}{0.2}\right)}{0.0085}$$

RESULT (Case 6): $t = 434 \text{ years}$

Model Applied to Case 7: Intensive Pump and Treat With 5 Years of Pumping

$$k_s = \frac{87.5 \frac{\text{kg}}{\text{yr}}}{4100 \text{ kg}} = 0.021 \text{ yr}^{-1}$$

$$\frac{C_{\text{lyr}}}{C_{\text{now}}} = e^{-k_s t}$$

Starting concentration under pumping conditions: 0.056 mg/L (due to mass-transfer effects for deep and middle units; factor of 3.6 reduction).

$$\frac{C_{5\text{yr}}}{0.056 \text{ mg/L}} = e^{-(0.021 \text{ yr}^{-1})(5\text{yr})}$$

$$C_{5\text{yr}} = 0.050 \text{ mg/L}$$

Time to cleanup after 5 yrs of pumping is finished, with 3.6-times increase in concentration due to rebound ($0.050 \text{ mg/L} \times 3.6 = 0.18 \text{ mg/L}$).

May 21, 2001



$$\frac{0.005 \text{ mg/L}}{0.18 \text{ mg/L}} = e^{-(0.00085 \text{ yr}^{-1})(t \text{ yrs})}$$

$$t = \frac{-\ln\left(\frac{0.005}{0.18}\right)}{0.0085}$$

$$t = 422 \text{ years}$$

RESULT (Case 7): Total time to cleanup (Intensive Pump-and-Treat for 5 yrs) = 5 + 422 = **427 years**

CONCLUSION: Comparison of Cleanup Times – Sites G/H/L

Case 6	Natural Attenuation Only – Sites G/H/L.....	434 years
Case 7	30 Yrs of Intensive Pump-and-Treat + Natural Attenuation – Sites G/H/L	427 years

GSI Job No. G-2876
April 1, 2004



ATTACHMENT 3

**Technical Memorandum Regarding Applicability of Uniform Concentration
to Mass Ratio Assumption, October 28, 2003**

Sauget Area 1 Sites
Sauget, Illinois



TECHNICAL MEMORANDUM

TO: Mr. Bruce Yare, Solutia Inc.

FROM: Chuck Newell, James Kearley, and Shahla Farhat

RE: Applicability of Uniform Concentration to Mass Ratio Assumption, Workplan for DNAPL Characterization and Remediation Study, Sauget Area 1, Sauget, Illinois

BACKGROUND

The Workplan for DNAPL Characterization and Remediation Study submitted by Solutia Inc. to the U.S. Environmental Protection Agency (U.S. EPA) included results from a Source Evaluation Study prepared by Groundwater Services, Inc. (see Appendix C in the Workplan). These results were summarized in the DNAPL Workplan as:

Planning-level calculations by GSI suggest that removal of 99.97% or 99.96% of the DNAPL mass could be needed to achieve ARARs within 5 years or 30 years, respectively. The key assumptions for these calculations were i) an assumed starting source mass of 410,000 kg of DNAPL; and ii) changes in COC concentrations in groundwater are directly proportional to changes in DNAPL mass in the aquifer matrix.

In response, the U.S. EPA commented on the assumption that concentrations in groundwater are directly proportional to changes in DNAPL mass:

"... it is recommended that the workplan or final report fully discuss and evaluate the reasons for using the assumption, and provide alternative approaches to estimating NAPL removal for comparison."

We appreciate the insightful comment from the U.S. EPA, since predicting DNAPL source zone response is currently a critical remediation issue, and is an active research area in which Groundwater Services, Inc. is participating. Predicting source zone response was discussed in detail during C. Newell's work on the EPA's Expert Panel on DNAPL Source Depletion. Groundwater Services, Inc. (GSI) is now charged with developing tools to transfer the current state of knowledge regarding source zone response as part of a Strategic Environmental Research and Development (SERDP) research grant. (This project is known as the Decision Support System to Evaluate Effectiveness and Cost of Source Zone Treatment).

SOURCE DECAY MODELING PROCEDURES

The source decay model used for the Sauget Area 1 Source Evaluation Study was originally presented in the BIOSCREEN model (Newell et al, 1996). Since that time there has been an increased focus on the relationship between concentration (and mass flux) vs. DNAPL mass.

Sale and McWhorter (2001) developed a multiple analytical source superposition technique (MASST) where a heterogeneous DNAPL architecture was conceptualized as a series of discrete subzones containing DNAPL (i.e., fingers and pools) separated by portions of the aquifer entirely free of DNAPL. The groundwater flow field was considered to be uniform. Using the MASST model, Sale and McWhorter concluded that "remediations that reduce DNAPL saturations will have little effect on near-term groundwater quality" and that "removal of the vast majority of the DNAPL will likely be necessary to achieve significant near-term improvements in groundwater quality."

However, other research by Rao and Jawitz (2003) and by Rao et al. (2001) reached a different conclusion: "We contend that in heterogeneous formations, significant contaminant flux reductions can be realized through partial mass reduction in DNAPL source zones." (Rao and Jawitz, 2003).

These different source response models were summarized by Stroo et al., (2003) using curves that show concentration reduction (in the form of mass flux reduction) vs. source mass reduction. In a modified version of their presentation, the results from Sale and McWhorter (2001) are plotted as the curve no. 5 in Figure 1. Source mass reductions of greater than 80% are required to reduce source concentrations (i.e., mass flux) more than 10%. However, theoretical results from Enfield et al., (2002) and Rao and Jawitz (2003) (curves 1 and 2) show that for a given reduction in source mass, a larger reduction in mass flux results. For example, the Rao and Jawitz curve no. 1 shows that a 40% reduction in source mass would yield a 75% reduction in mass flux.

Note that curve 3 represents the case where source mass reduction causes an equivalent reduction in mass flux. In other words, curve 3 reflects the assumption that concentrations in groundwater are directly proportional to changes in DNAPL mass (if there is no change in the groundwater flow field before and after remediation). This was the assumption that was used in the Sauget Area 1 Source Evaluation Study and was referenced in the DNAPL Workplan.

It is our opinion that the source zone assumption referenced in the DNAPL Workplan represents the middle ground in a research area where at present there is no widely accepted approach or model. For example, Stroo et al. (2003) concluded that the "ability of source removal technologies to improve groundwater quality and reduce overall plume management costs is controversial." An Expert Panel convened by EPA (report in press) has concluded that there is considerable uncertainty regarding the relationship between source mass reduction and the reduction in mass flux from the source zone. (C. Newell was a member of this Expert Panel).

Rather than present widely different models for source response in the DNAPL Workplan, some which would show dramatic changes in concentration and some which would show almost no changes in concentration, we suggest that the DNAPL Workplan retain the existing source response model. This model represents the "middle ground" of current approaches and should provide results that are adequate for "planning level calculations" for evaluating how various remediation approaches might affect the remediation timeframe for Sauget Area 1.

C. Newell, J. Kearley, and S. Farhat

REFERENCES

- Enfield, C. G.; Wood, A. L.; Brooks, M. C.; Annable, M. D, 2002. Interpreting tracer data to forecast remedial performance. In *Groundwater Quality: Natural and Enhanced Restoration of Groundwater Pollution*, Thornton, S. Oswald, S., Eds., IAHS: Sheffield, United Kingdom, 2002; pp 11-16.
- Newell, C.J., J. Gonzales, and R. McLeod, 1996. BIOSCREEN Natural Attenuation Decision Support System, U.S. Environmental Protection Agency. EPA/600/R-96/087, August, 1996.
- Rao, P. S. C.; Annable, M. D.; Sillan, R. K.; Dai, D.; Hartfield, K.; Graham, W. D., 1997. *Water Resour. Res.* 1997, 33, 2673-2686.
- Rao, P.S.C., and J.W. Jawitz. 2003. Comment on Steady-state mass transfer from single-component dense non-aqueous phase liquids in uniform flow fields by T.C. Sale and D.B. McWhorter, *Water Resour. Res.*, (In Press).
- Rao, P.S.C., J.W. Jawitz, C.G. Enfield, R.W. Falta, M.D. Annable, and A.L. Wood. 2001. Technology integration for contaminated site remediation: Cleanup goals and performance criteria. pp, 571-578, In: *Groundwater Quality: Natural and Enhanced Restoration of Groundwater Pollution*, Publication No. 275, International Association of Hydrologic Sciences, Wallingford, United Kingdom.
- Sale, T.C. and McWhorter, D.B. 2001. Steady State Mass Transfer from Single-Component DNAPLs in Uniform Flow Fields. *Water Resources Research*, 37(2), 393-404.
- Stroo, H. F., M. Unger; C. H. Ward; M. C. Kavanaugh; C. Vogel; A. Leeson; J. A. Marqusee; B. P. Smith, 2003. Remediating *Chlorinated Solvent* Source Zones, *Environmental Science & Technology*, Volume 37, No. 11, page 225A – 230A.

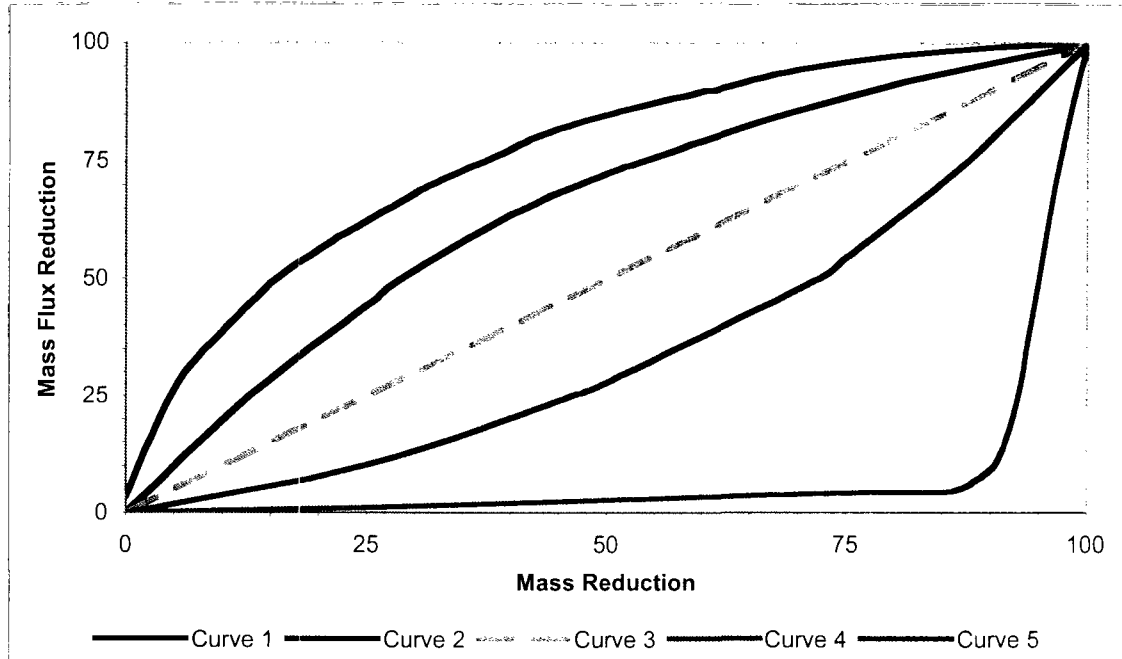


Figure 1. Different Flux Reduction vs. Mass Reduction Curves. The dashed curve (Curve 3) was used for the Sauget Area 1 Source Evaluation Study.

Sources: Curve 1 (top curve): Rao and Jawitz, 2003;

Curve 2: Enfield et al., 2002;

Curve 3: Newell et al., 1996;

Curve 4: Rao et al., 1997;

Curve 5 (bottom curve): Sale and McWhorter, 2001.

Note that mass flux reduction is equivalent to average concentration reduction in the case where the groundwater flow field does not change.



Appendices

GSI Job No. G-2876
April 1, 2004



**WORK PLAN FOR DNAPL CHARACTERIZATION AND
REMEDATION STUDY**

Sauget Area 1 Sites
Sauget, Illinois

LIST OF ATTACHMENTS

ATTACHMENT A FIELD SAMPLING PLAN

ATTACHMENT B PROJECT HEALTH AND SAFETY PLAN

GSI Job No. G-2876
April 1, 2004



ATTACHMENT A

FIELD SAMPLING PLAN

Work Plan for DNAPL Characterization and Remediation Study

Sauget Area 1 Sites
Sauget, Illinois

FIELD SAMPLING PLAN

Work Plan for DNAPL Characterization and Remediation Study Sauget Area 1 Sites, Sauget, Illinois

1.0 INTRODUCTION

1.1 Scope and Application

This Field Sampling Plan presents Standard Operating Procedures (SOPs) for field sampling and testing methods for the "Work Plan for DNAPL Characterization and Remediation Study" for the Sauget Area 1 Sites in Sauget, Illinois. The following sections provide guidelines for the field tasks to be employed during the field program.

A detailed scope of work is presented in the Work Plan. A project Health and Safety Plan and a Quality Assurance Project Plan (QAPP) have also been prepared and contain additional specifications and procedures.

Additional information and supplemental guidance for field procedures is included in several U.S. EPA SOPs included in Attachment A of this Field Sampling Plan. As stated, "These are standard (i.e. typically applicable) operating procedures which may be varied or changed as required dependent on site conditions, equipment limitations, or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report." In the event of conflicting procedures, the project-specific procedures described in this Field Sampling Plan will take precedence over the supplemental guidelines in Attachment A.

1.2 Work Program Objectives

The primary objectives of the DNAPL Characterization and Remediation Study Work Plan are: i) estimation of the volume of DNAPL-affected material; ii) assessment of the ability to remove DNAPL from the aquifer matrix by treatment; iii) estimation of the removal efficiencies of various treatment technologies; and iv) determination of the presence of pooled DNAPL.

1.3 General Guidelines

To achieve project objectives, NAPL samples and soil samples will be collected and analyzed for a variety of field and laboratory parameters. Piezometers will be installed to investigate for the presence of pooled DNAPL on the bedrock surface underlying the alluvial aquifer. The following sections provide guidelines and procedures to be used in performance of these field tasks. The following information summarizes some general guidelines that apply to all field sampling operations.

- **Sample Handling:** Proper sample handling is important to minimize interferences such as cross-contamination and loss of volatile constituents. Due care must be taken in the collection and handling of all samples.
- **Sample Numbering:** All samples for laboratory analysis are to be assigned a unique sample identification number. The sample numbering system is illustrated on Figure 5.2 of the QAPP.
- **Sample Custody:** All samples for laboratory analysis will be transferred to the laboratory under chain-of-custody control. Samples should be maintained at proper temperature pending shipment, and transferred to the laboratory as soon as practical, preferably within 24, and not more than 48 hours of collection. Additional field custody procedures are provided in Section 5.1 of the QAPP
- **Record Keeping:** Records of all field activities will be maintained in field data sheets or log books in standardized formats. Information to be recorded each day that field work is performed will include the following, as applicable:
 - Identification of sampling personnel;
 - General weather conditions;
 - Identification, location, depth, and description of soil and/or NAPL samples;
 - Dates and times of measurement/sample collection;
 - Results of all field measurements or field tests;
 - Construction specifications for newly installed piezometers, including total depth, and the height/position of the well screen, filter pack, annular seal, etc.;
 - Deficiencies in the physical condition of wells noted during well inspections;
 - Well development methods and volumes;
 - Analyses to be performed, container types, and preservatives;
 - Any particular condition or circumstance which could adversely impact the achievement of project goals. These should be brought to the immediate attention of the GSI and/or Solutia project managers.

2.0 NAPL SURVEYS AND RECOVERY TESTS

2.1 Well Surveys to Measure NAPL Thickness

Monitoring wells and piezometers will be surveyed to evaluate the possible presence of light and dense non-aqueous phase liquids (LNAPL and DNAPL). To minimize the potential for cross-contamination, wells where NAPL is not expected will be surveyed first, followed by wells where NAPL could be present. (Note: In this document, monitoring wells and piezometers are often collectively referred to as "wells.")

At each well, the survey will include measurement of the depth to water to the nearest 0.01 ft and a check for the presence of LNAPL or DNAPL using an electronic interface probe. One interface probe (the "clean probe") will be used at wells where NAPL is not expected, and a second interface probe (the "dirty probe") will be used for wells where NAPL could be present. The interface probes are to be decontaminated between wells as described in Section 7.0.

As a visual check for LNAPL, a disposable clear bailer made of Teflon or PVC will be lowered to the water level in each well and then inspected for the presence or absence of LNAPL. A visual check for DNAPL will be performed by lowering a weighted cotton string to the bottom of the well, then retrieving the string to inspect for evidence of staining. Finally, the disposable bailer will be lowered to the bottom of each well to check for the presence of accumulated DNAPL. New string, bailers, and bailer cord will be used at each well.

2.2 NAPL Field Measurements and Observations

At each well where free-phase NAPL is noted, a small volume of NAPL will be collected for field measurements and observations. The field measurements will include density, viscosity, and temperature.

NAPL Density: A sample of the NAPL will be placed into a suitable glass beaker or cylinder. NAPL density will then be measured by lowering a wide-range specific gravity hydrometer into the container of NAPL. The hydrometer used for testing DNAPL samples will likely have a specific gravity measurement range of approximately 1.00 to 2.00. The hydrometer used for testing LNAPL samples will likely have a specific gravity measurement range of approximately 0.65 to 1.00.

NAPL Temperature and Viscosity: NAPL temperature will be measured using a general-purpose mercury thermometer, and NAPL viscosity will be measured using an aluminum dip viscosity cup with a removable stainless steel orifice. The dip cup will be lowered into a container of the NAPL so that the top rim of the cup is submerged. The thermometer will be placed into the cup as it is immersed to determine the temperature of the NAPL inside the cup. After the thermometer is removed, the dip cup will be lifted out of the NAPL using a quick steady motion to a height of no more than about 6 inches above the level of the NAPL in the container. As the cup breaks the surface of the liquid a timer will be started. The timer will be stopped when the first definite break in the stream at the base of the cup is observed. The efflux time and temperature will be recorded in the field notes, and the dip cup and orifice will be thoroughly cleaned as discussed in Section 7.0. The orifice should be carefully cleaned using a length of nylon fishing line. This viscosity measurement procedure will be repeated so that a second measurement of efflux time is obtained for each sample. The NAPL viscosity can then be estimated using the average efflux time along with the manufacturer's calibration data for the dip cup.

Possible Problems with Field Measurements: Field measurements of density and viscosity cannot be made if sufficient sample volume is not recovered from a well. In addition, accurate field measurements of NAPL viscosity cannot be made for highly viscous NAPL and for NAPL containing a high sediment content, both of which would result in fouling or plugging of the dip cup orifice. In these situations, the alternative approach will be to rely on i) field measurements from other nearby wells and piezometers; and ii) laboratory measurements of density and viscosity that will be conducted on composite NAPL samples, as discussed in Section 3.2.

NAPL Wettability: Qualitative observations of NAPL wettability will be made by checking the spreading of NAPL injected into separate beakers containing glass beads, sand, and rock fragments. These observations will be documented using notes and photographs.

3.0 NAPL Recovery Tests and Sampling

NAPL recovery tests will be conducted at selected wells where NAPL is found, and NAPL samples will be collected for laboratory measurement of physical and chemical properties. NAPL recovery tests and NAPL sampling will be conducted according to the procedures described below.

3.1 NAPL Recovery Tests

NAPL recovery tests will be performed using a peristaltic pump, inertial lift pumping equipment with disposable downhole components (i.e., Waterra tubing and foot valves), or another suitable pumping method. The pumping rate will be set to minimize the volume of water pumped during each test by performing a visual inspection of fluid samples collected in closed flasks.

The volume of NAPL and the volume of water produced will be recorded at 15-minute intervals. The volume of NAPL and volume of water recovered during each test will be determined by measuring accumulations in a collection vessel such as a closed tank or drum. Qualitative observations of NAPL wettability will be made as discussed in Section 2.2.

It is anticipated that the recovery tests will be conducted with alternating periods of pumping and resting. If NAPL volume in the recovered fluids decreases substantially after an initial period of pumping, then pumping will be stopped temporarily to allow time for additional NAPL to enter the well screen and accumulate in the well. A NAPL recovery test at a well will be terminated when at least one of the following conditions is met: i) the recovery test has been conducted for at least 8 hours; ii) a total of at least 100 gallons of fluids has been recovered; or iii) no measurable NAPL has been recovered during at least two consecutive pumping and rest cycles following the initial pumping period.

At the conclusion of each recovery test, the well will be resurveyed for the presence of NAPL using the interface probe, weighted cotton string, and disposable bailer, as described in Section 2.1.

3.2 Collection, Handling, and Preservation of NAPL Samples

A total of three liters of NAPL, four 10-mL vials of NAPL, and one liter of water will be collected at each well where a recovery test is conducted, assuming that this quantity of NAPL can be obtained. If a well has both DNAPL and LNAPL, then two separate sets of NAPL sample bottles will be collected for that well, one set for DNAPL and one set for LNAPL. The sample containers will be placed on ice pending completion of the recovery tests.

Composite samples of DNAPL and water (as well as LNAPL if present) will be prepared for each of the four fill areas (i.e., Sites G, H, I, and L). These composite samples will be submitted for laboratory analysis of physical and chemical properties and for treatability testing. Each of the four composite samples will consist of the following: i) one liter of NAPL and one liter of water for measurement of physical properties (i.e., dynamic viscosity, fluid density, surface tension, interfacial tension); ii) four 10-mL vials (or equivalent) of NAPL for analysis of VOCs, SVOCs, pesticides, herbicides, PCBs, dioxin, and metals; iii) one liter of NAPL for thermal treatability testing; and iv) one liter of NAPL for possible surfactant treatability testing.

4.0 DRILLING AND SOIL SAMPLE COLLECTION

4.1 Soil Sampling Methods

Soil borings will be advanced at selected locations using rotasonic drilling equipment. For these soil borings, continuous soil sampling will be conducted from the ground surface to approximately 5 feet into the bedrock, with a total depth of approximately 110 feet below ground surface. During drilling, a 4-inch diameter core barrel will be advanced to collect continuous soil cores. A 6-inch diameter steel over-ride casing will be advanced over the inner drill rods and core barrel to stabilize the borehole. In addition, a 7-inch diameter over-ride casing will be used to isolate the fill materials at drilling locations within the fill areas. Although soil samples will generally be collected using the rotasonic core barrel (see Section 4.3), a split-spoon sampling device will be used whenever an undisturbed soil core is needed (see Section 4.2).

Sampling tools and equipment should be thoroughly cleaned as described in Section 7 below, or be of the disposable, single use variety. Sampling tools such as trowels and knives should be made of non-reactive materials.

4.2 Collection, Handling, and Preservation of Undisturbed Soil Cores

Undisturbed cores (three per boring) will be collected for the purpose of physical properties testing (i.e., porosity, bulk density, and grain size). Undisturbed cores (three cores from each of the three potential DNAPL source areas) will also be collected for the purposes of laboratory analysis of pore fluid saturations and/or evaluation of DNAPL mobility. The undisturbed core samples will be collected using a split spoon-sampling device.

These cores will not be examined or screened for NAPL in the field. Instead, each core will be preserved using the following procedure. Immediately upon collection of the core, a special core handling tool will be used to separate the top half of the split spoon sampler from the core by sliding the tool in along the inside wall of the split-spoon sampler while lifting the top half of the sampler. A plastic core tray will be placed over the exposed half of the core. The tray, core, and bottom half of the split-spoon sampler will be held together and rotated 180 degrees. The core tool will be used to separate the remaining half of the split-spoon sampler from the core, so that the core is sitting in the tray. The core and tray will then immediately be placed on dry ice. After the core freezes, the core and tray will be wrapped with Saran wrap and placed back on dry ice for storage.

4.3 Collection, Handling, and Preservation of Soil Samples

Soil cores collected for the purpose of lithologic/stratigraphic description, NAPL screening, and laboratory analysis of NAPL constituents will be collected using the 10-ft long rotasonic core barrel. During drilling, the 4-inch diameter core barrel will be advanced to collect continuous soil cores. A 6-inch diameter steel over-ride casing will be advanced over the inner drill rods and core barrel to stabilize the borehole. After retracting the core barrel from the borehole, the core will be extruded into two 5-ft long, heavy-ply polyethylene tubes and placed flat on an aluminum trough table for examination. The sample tubes will be cut laterally with a razor knife along the full length of the core.

The length of the soil core recovered relative to the length of the sample interval will be recorded on the boring log. The core will then be carefully cut lengthwise to reveal the interior. During sample examination and handling, a clean work surface will be maintained. The samples will be handled with clean gloves and clean tools to minimize potential cross-contamination.

A representative portion of each 2.5-foot interval from the 10-foot soil core will be retained in a sealed plastic bag at ambient temperature for organic vapor head-space screening with a photo-ionization detector (PID), as described in Section 4.5. Prior to soil core examination and NAPL screening, a soil sample will be retained from each 2.5-foot interval of core for potential analysis of VOCs, SVOCs, and TOC. Soil samples should be carefully handled to minimize loss of volatile constituents. The laboratory will provide pre-weighed vials with methanol preservative, and these vials will be used for the sample

aliquots retained for VOC analysis. The sample aliquots to be analyzed for VOCs should be collected first and retained on ice. Samples for other analyses (i.e., SVOCs and TOC) are then collected in clean glass containers and retained on ice. In addition, a total of three "clean" soil samples (i.e., with little or no evidence of NAPL) will be retained from each boring for analysis of fraction organic carbon.

The approach described above for the collection, handling, and preservation of samples for VOC analyses is appropriate for this sampling program. These soil samples, which will come from potential NAPL source areas, are intended to provide chemical constituent data that can be used to help develop gross estimates of the volume of DNAPL-affected material at the source areas (see the work program objectives in Section 1.2). These soil samples are not intended for lateral delineation of affected soils to background concentrations. Therefore, in this work program it should not be necessary to use the En Core sampling system for VOCs.

A total of four soil samples are to be retained from each 10-foot core (i.e., one sample per 2.5-ft interval, as noted above). Of the four samples from each 10-foot core, a total of one sample will be selected for laboratory analysis of chemical constituents (i.e., VOCs, SVOCs, and TOC). The sample will be selected using the criteria outlined in Section 4.6, based on the results of soil core examination, NAPL screening, and organic vapor head-space screening.

4.4 Soil Core Examination and NAPL Screening

All cores will be digitally photographed. Each photograph will include a scale, core ID, and date of collection. Soil cores will be logged in accordance with the Unified Soil Classification System (USCS) and examined for qualitative moisture content (e.g., dry, moist, or saturated).

Soil cores will be carefully examined for the presence or absence of visible NAPL, sheen, staining, or organic chemical odor, and the depth intervals over which such conditions occur will be noted on the log. If visible NAPL is present, the NAPL will be described, and the nature of NAPL occurrence will be qualitatively evaluated and described in detail on boring logs (e.g., NAPL occurs as layers parallel bedding, as discrete droplets, etc.). Soil cores with no visible NAPL will be further evaluated using the following methods to confirm NAPL absence.

Shake Tests and Sudan IV Dye Tests: These tests will be performed using vial test kits containing Sudan IV dye that are available from Cheiron Resources Ltd. To evaluate a soil core for DNAPL using the vial test kit, measured volumes of soil and water are added to a test vial and agitated. Within the vial, a sugar cube that contains a pre-measured mass of Sudan IV dye dissolves during the agitation and stains any NAPL red. Another dye within the sugar cube stains the water green, which makes the red dye more visible. Agitation of the sample will continue until the sugar cube is entirely dissolved, and the jar will then be inspected for evidence of NAPL. If there is no indication of NAPL, the sample will be agitated again, allowed to sit for a minimum of 5 minutes, and reinspected. If no

areas of red coloration develop within the jar over at least a 5-minute period, the test will be considered negative for NAPL.

Tests Using FLUTE Strips: Strips of dye-impregnated NAPL FLUTE™ ribbon material will be pressed directly against the soil cores and inspected for a reaction.

4.5 Organic Vapor Head-Space Screening

Representative portions of soil cores are retained in polyethylene bags (zip-lock type) at ambient temperature for organic vapor headspace testing using a photo-ionization detector (PID). The calibration of the PID is to be verified daily using the procedures specified in the operating manual for the PID. Headspace testing should be conducted not less than 5 minutes following sample collection to allow off-gassing of organic vapors, but should be performed on the day of sampling. Soil samples for PID testing must be retained in polyethylene bags at ambient temperature from time of collection to time of testing. At the time of testing, the bag closure is loosened and the PID probe is inserted into the minimum necessary opening and the maximum deflection of the meter is recorded as an indication of relative VOC content.

A bag blank must be tested for off-gassing of the plastic. An otherwise empty bag should be sealed with some entrapped air at the beginning of the each sampling day, and the bag retained at ambient temperature over the course of the day. The air in the bag should then be tested with the bagged soil samples and the results recorded in the field log.

Note that organic vapor screening should always be used in conjunction with descriptions of appearance and odor. In selection of soil samples for laboratory analysis, all aspects of the sample description must be taken into account.

4.6 Criteria for Determining Which Soil Samples to Submit for Lab Testing

A total of four soil samples are to be retained from each 10-foot core (i.e., one sample per 2.5-ft interval, as noted in Section 4.3). Of the four samples from each 10-foot core, a total of one sample will be selected for laboratory analysis of chemical constituents (i.e., VOCs, SVOCs, and TOC), based on the following criteria.

If NAPL is noted in a 10-foot soil core based on visual inspection or other evidence (i.e., shake tests, Sudan IV dye tests, and/or FLUTE strips), the soil sample retained for laboratory analysis will be from the interval of the core that has the most obvious indications of NAPL. If there are no field indications of NAPL in the 10-foot core, the soil sample for laboratory analysis will be from the interval exhibiting the maximum other evidence of organic constituents, based on a combination of odor, appearance, and/or organic vapor head-space testing results.

4.7 Field Quality Assurance / Quality Control

Field quality assurance/quality control (QA/QC) samples including blanks, field duplicates, and matrix spike/matrix spike duplicate samples will be collected to provide QA/QC control on field and laboratory procedures. Trip blanks and equipment blanks will be used to detect potential deficiencies in sample collection and handling and equipment decontamination procedures. Duplicate samples will be collected to provide a check on laboratory repeatability. Matrix spike and matrix spike duplicates (MS/MSD) will be collected to provide checks on analytical procedures.

Field duplicate samples will be submitted at a rate of 1 for every 10 samples to be analyzed. MS/MSD pairs will be submitted at a rate of 1 for every 20 samples to be analyzed. Field duplicate and MS/MSD samples are collected in the same manner as the regular soil samples.

Care must be taken to ensure that field duplicates and MS/MSD pairs are as nearly identical to the original sample as possible. Sample homogenization in a clean stainless-steel mixing bowl or similar device is recommended for SVOC and TOC analyses, but could potentially result in loss of volatile constituents. Therefore, duplicate and MS/MSD samples for VOC analyses should be discrete grab samples.

Duplicate samples from a given location will be designated by the suffix "A" or "B" at the end of the sample identification number. MS/MSD samples will be designated by the suffix "MS" or "MSD" at the end of the sample identification number.

One set of trip blank samples for VOC analyses only will be prepared for each sample cooler containing VOC samples. Trip blanks are prepared in the laboratory and accompany the sample kit throughout the sampling program. Trip blank samples are designated "TB-(mo/dy/yr)-n," where n is the sequence number if more than 1 trip blank is submitted for the day.

One set of equipment blank samples for analysis of each group of analytes to be tested, will be prepared for each day of the sampling program, for each type of sampling device (e.g., core barrel, or trowels and knives). If all equipment of a certain type is either dedicated or disposable (e.g., sample scoops), an equipment blank for that type of device will not be required.

Equipment blanks are prepared by decontaminating the equipment in the standard manner as described in Section 7, and running distilled water through the device and into a beaker or other container and decanting to the appropriate sample container. Equipment blank samples are designated "EB-(mo/dy/yr)," followed by a suffix indicating the equipment type.

5.0 PIEZOMETER INSTALLATION

5.1 Piezometer Materials and Screen Placement

A piezometer will be installed following completion of drilling and soil sampling at each of the eighteen proposed soil borings in this work program. Each piezometer will be constructed of 2-in diameter, flush-threaded stainless steel riser with 15 feet of stainless steel wire-wound screen. The piezometer screen will extend across the interface of the alluvial aquifer and the underlying bedrock surface.

5.2 Filter Pack

Filter packs will be composed of graded silica sand and typically extended 1 to 2 ft above the top of the screen. Filter pack should be sized according to the formation lithology: 20-40 sand is used in fine grained formations (i.e., silts) and 16-30 or 10-20 grades are used in coarser sand and gravel formations.

Installation of the sand pack will be accomplished by incrementally adding small amounts of sand inside the six-inch override casing and incrementally retracting the override casing such that the riser and/or screen are not exposed to the open borehole. Potable water may be used as needed to eliminate bridging, but addition of water should be minimized, the volume recorded, and the volume of water removed during development increased accordingly. The final elevation of the sand pack will be determined by tagging the top of the sand pack with a sounding weight around the annular space. The well log should include the number of sacks of sand used.

5.3 Annular Seal

A 1 to 2-ft thick bentonite seal will be placed on the top of the sand pack prior to placement of grout in the annular space. Bentonite in pellet or granular form will be installed inside the override casing. The volume of pellets or granules should be recorded on the well log.

The bentonite pellets or granular bentonite will be allowed to hydrate for approximately 30 minutes prior to sealing the remaining annular space with grout. Final elevation of the bentonite seal will be determined by tagging the elevation of the top of the bentonite seal with a sounding weight around the annular space.

A cement-bentonite grout will be placed by a tremie pipe into the remaining annular space from the top of the bentonite seal to the ground surface. It may be necessary to top off the seal after a minimum of 24 hours has passed following placement if settlement occurs. A minimum 48-hour curing period will elapse before the piezometer is developed.

5.4 Surface Completion

The piezometers will be completed at ground surface with locking protective casings and guard posts, or below grade with a water-tight lockable housing, depending upon traffic conditions at the particular location. Top-of-casing elevations for piezometers will be surveyed to the nearest 0.01 foot relative to an established benchmark referenced to mean sea level. Ground surface elevations for piezometers will be surveyed to the nearest 0.1 foot relative to an established benchmark referenced to mean sea level.

5.5 Piezometer Development

Piezometers should be developed as soon as practical following installation, but at least 48 hours should be allowed following grout placement prior to development to allow the grout adequate time to cure. Development may be conducted by i) air-lift pumping, ii) surging and pumping; and/or iii) surging and bailing, depending on the well yield.

If feasible, well development for all newly installed piezometers will proceed until: i) the produced water is relatively free of silt and fines; ii) a minimum of ten well casing volumes are removed; and iii) three successive, stabilized readings of temperature, specific conductance, and pH, are separated by the removal of at least 0.5 well casing storage volume, are recorded. Stabilized readings are defined as readings which exhibit $\leq 10\%$ change in specific conductance, a 0.2 standard units change in pH, and a 2.0 degree F change in temperature. Deviations from these standards must be noted in the log book.

5.6 Survey of New Piezometers to Measure DNAPL Thickness

Following completion of development, the depth to water and total depth of each piezometer will be measured, and each piezometer will be checked for the possible presence of DNAPL, as described in Section 2.1. To allow for possible accumulation of DNAPL, each new piezometer will be left undisturbed for a period of at least a week and then resurveyed for DNAPL. A DNAPL recovery test will be conducted at each new piezometer that has a confirmed thickness of free-phase DNAPL of at least 0.5 foot. It is expected that LNAPL will not be present in the new piezometers, since they will all be screened significantly below the water table of the alluvial aquifer.

6.0 MANAGEMENT OF INVESTIGATION-DERIVED WASTES

Soil Cuttings: Soil cuttings generated during soil sampling and piezometer installation activities will be collected in labeled drums, rolloff boxes, or other suitable containers and tested, as needed, for characterization prior to off-site disposal. Each container will be given a unique identification number and labeled as to contents and date filled. A log will be maintained indicating the contents, location and status of all containers of soil cuttings.

Water: Water generated from piezometer development and from equipment decontamination activities will be collected in labeled drums or other suitable containers and managed at the on-site effluent treatment facility.

NAPL: NAPL generated during NAPL recovery tests will be collected in labeled drums or other suitable containers and tested, as needed, for characterization and management by Solutia. Each container will be given a unique identification number and labeled as to contents and date filled. A log will be maintained indicating the contents, location and status all drums filled.

PPE and Miscellaneous Wastes: All disposable personal protective equipment and disposable sampling equipment will be collected in appropriate containers for management by Solutia.

7.0 DECONTAMINATION

Use of clean sampling equipment is essential to minimize cross-contamination of samples or wells. The following procedures should be used for sampling equipment.

Electronic Interface Probe: To prevent cross-contamination between wells, the electronic interface probes (the "clean probe" and the "dirty probe") will be decontaminated after use in each well by the following procedure: i) wipe the probe and tape with a paper towel soaked in acetone; ii) wash with a detergent solution (Alconox® or equivalent); iii) rinse with clean water; iv) rinse again with deionized water; and v) dry using paper towels.

Drilling and Sampling Equipment: All down-hole drilling and sampling equipment (e.g., core barrels for soil sampling) must be decontaminated prior to arrival at the project site, prior to use at each location if chemical analysis is to be performed, and prior to leaving the job site. Drilling equipment will be decontaminated using a portable high-pressure hot-water cleaner. Alconox® or equivalent detergents shall be used as needed.

Other Equipment: Other miscellaneous equipment, including sample knives, trowels, and downhole pumps, which come in direct contact with the sampled medium, shall be decontaminated prior to each use with an Alconox® or equivalent detergent solution, rinsed with clean water, rinsed again with deionized water, and towel or air dried.

FIELD SAMPLING PLAN

Workplan for DNAPL Characterization and Remediation Study

Sauget Area 1 Sites
Sauget, Illinois

Attachment A

Supplemental Field Sampling Guidelines

<u>EPA SOP No.</u>	<u>Title</u>
2001	General Field Sampling Guidelines
2006	Sampling Equipment Decontamination
2012	Soil Sampling
2044	Monitor Well Development
2048	Monitor Well Installation
2114	Photoionization Detector (PID) HNU

Note: These SOPs were downloaded from the website of the U.S. EPA Environmental Response Team. http://www.ertresponse.com/Response_resrcs/Index.htm



GENERAL FIELD SAMPLING GUIDELINES

SOP#: 2001
DATE: 08/11/94
REV. #: 0.0

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to provide general field sampling guidelines that will assist REAC personnel in choosing sampling strategies, location, and frequency for proper assessment of site characteristics. This SOP is applicable to all field activities that involve sampling.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent on site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

Mention of trade names or commercial products does not constitute U.S. EPA endorsement or recommendation for use.

2.0 METHOD SUMMARY

Sampling is the selection of a representative portion of a larger population, universe, or body. Through examination of a sample, the characteristics of the larger body from which the sample was drawn can be inferred. In this manner, sampling can be a valuable tool for determining the presence, type, and extent of contamination by hazardous substances in the environment.

The primary objective of all sampling activities is to characterize a hazardous waste site accurately so that its impact on human health and the environment can be properly evaluated. It is only through sampling and analysis that site hazards can be measured and the job of cleanup and restoration can be accomplished effectively with minimal risk. The sampling itself must be conducted so that every sample collected retains its original physical form and chemical composition. In this way, sample integrity is insured, quality assurance standards are maintained, and the sample can accurately represent the larger body of

material under investigation.

The extent to which valid inferences can be drawn from a sample depends on the degree to which the sampling effort conforms to the project's objectives. For example, as few as one sample may produce adequate, technically valid data to address the project's objectives. Meeting the project's objectives requires thorough planning of sampling activities, and implementation of the most appropriate sampling and analytical procedures. These issues will be discussed in this procedure.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

The amount of sample to be collected, and the proper sample container type (i.e., glass, plastic), chemical preservation, and storage requirements are dependent on the matrix being sampled and the parameter(s) of interest. Sample preservation, containers, handling, and storage for air and waste samples are discussed in the specific SOPs for air and waste sampling techniques.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

The nature of the object or materials being sampled may be a potential problem to the sampler. If a material is homogeneous, it will generally have a uniform composition throughout. In this case, any sample increment can be considered representative of the material. On the other hand, heterogeneous samples present problems to the sampler because of changes in the material over distance, both laterally and vertically.

Samples of hazardous materials may pose a safety threat to both field and laboratory personnel. Proper health and safety precautions should be implemented when handling this type of sample.

Environmental conditions, weather conditions, or non-target chemicals may cause problems and/or interferences when performing sampling activities or when sampling for a specific parameter. Refer to the specific SOPs for sampling techniques.

5.0 EQUIPMENT/APPARATUS

The equipment/apparatus required to collect samples must be determined on a site specific basis. Due to the wide variety of sampling equipment available, refer to the specific SOPs for sampling techniques which include lists of the equipment/apparatus required for sampling.

6.0 REAGENTS

Reagents may be utilized for preservation of samples and for decontamination of sampling equipment. The preservatives required are specified by the analysis to be performed. Decontamination solutions are specified in ERT SOP #2006, Sampling Equipment Decontamination.

7.0 PROCEDURE

7.1 Types of Samples

In relation to the media to be sampled, two basic types of samples can be considered: the environmental sample and the hazardous sample.

Environmental samples are those collected from streams, ponds, lakes, wells, and are off-site samples that are not expected to be contaminated with hazardous materials. They usually do not require the special handling procedures typically used for concentrated wastes. However, in certain instances, environmental samples can contain elevated concentrations of pollutants and in such cases would have to be handled as hazardous samples.

Hazardous or concentrated samples are those collected from drums, tanks, lagoons, pits, waste piles, fresh spills, or areas previously identified as contaminated, and require special handling procedures because of their potential toxicity or hazard. These samples can be further subdivided based on their degree of hazard; however, care should be taken when handling and shipping any wastes believed to be concentrated regardless of the degree.

The importance of making the distinction between environmental and hazardous samples is two-fold:

- (1) Personnel safety requirements: Any sample thought to contain enough hazardous materials to pose a safety threat should be designated as hazardous and handled in a manner which ensures the safety of both field and laboratory personnel.
- (2) Transportation requirements: Hazardous samples must be packaged, labeled, and shipped according to the International Air Transport Association (IATA) Dangerous Goods Regulations or Department of Transportation (DOT) regulations and U.S. EPA guidelines.

7.2 Sample Collection Techniques

In general, two basic types of sample collection techniques are recognized, both of which can be used for either environmental or hazardous samples.

Grab Samples

A grab sample is defined as a discrete aliquot representative of a specific location at a given point in time. The sample is collected all at once at one particular point in the sample medium. The representativeness of such samples is defined by the nature of the materials being sampled. In general, as sources vary over time and distance, the representativeness of grab samples will decrease.

Composite Samples

Composites are nondiscrete samples composed of more than one specific aliquot collected at various sampling locations and/or different points in time. Analysis of this type of sample produces an average value and can in certain instances be used as an alternative to analyzing a number of individual grab samples and calculating an average value. It should be noted, however, that compositing can mask problems by diluting isolated concentrations of some hazardous compounds below detection limits.

Compositing is often used for environmental samples and may be used for hazardous samples under certain conditions. For example, compositing of hazardous waste is often performed after compatibility tests have

been completed to determine an average value over a number of different locations (group of drums). This procedure generates data that can be useful by providing an average concentration within a number of units, can serve to keep analytical costs down, and can provide information useful to transporters and waste disposal operations.

For sampling situations involving hazardous wastes, grab sampling techniques are generally preferred because grab sampling minimizes the amount of time sampling personnel must be in contact with the wastes, reduces risks associated with compositing unknowns, and eliminates chemical changes that might occur due to compositing.

7.3 Types of Sampling Strategies

The number of samples that should be collected and analyzed depends on the objective of the investigation. There are three basic sampling strategies: random, systematic, and judgmental sampling.

Random sampling involves collection of samples in a nonsystematic fashion from the entire site or a specific portion of a site. Systematic sampling involves collection of samples based on a grid or a pattern which has been previously established. When judgmental sampling is performed, samples are collected only from the portion(s) of the site most likely to be contaminated. Often, a combination of these strategies is the best approach depending on the type of the suspected/known contamination, the uniformity and size of the site, the level/type of information desired, etc.

7.4 QA Work Plans (QAWP)

A QAWP is required when it becomes evident that a field investigation is necessary. It should be initiated in conjunction with, or immediately following, notification of the field investigation. This plan should be clear and concise and should detail the following basic components, with regard to sampling activities:

- Ⓒ Objective and purpose of the investigation.
- Ⓒ Basis upon which data will be evaluated.
- Ⓒ Information known about the site including location, type and size of the facility, and length of operations/abandonment.
- Ⓒ Type and volume of contaminated material, contaminants of concern (including

concentration), and basis of the information/data.

- Ⓒ Technical approach including media/matrix to be sampled, sampling equipment to be used, sample equipment decontamination (if necessary), sampling design and rationale, and SOPs or description of the procedure to be implemented.
- Ⓒ Project management and reporting, schedule, project organization and responsibilities, manpower and cost projections, and required deliverables.
- Ⓒ QA objectives and protocols including tables summarizing field sampling and QA/QC analysis and objectives.

Note that this list of QAWP components is not all-inclusive and that additional elements may be added or altered depending on the specific requirements of the field investigation. It should also be recognized that although a detailed QAWP is quite important, it may be impractical in some instances. Emergency responses and accidental spills are prime examples of such instances where time might prohibit the development of site-specific QAWPs prior to field activities. In such cases, investigators would have to rely on general guidelines and personal judgment, and the sampling or response plans might simply be a strategy based on preliminary information and finalized on site. In any event, a plan of action should be developed, no matter how concise or informal, to aid investigators in maintaining a logical and consistent order to the implementation of their task.

7.5 Legal Implications

The data derived from sampling activities are often introduced as critical evidence during litigation of a hazardous waste site cleanup. Legal issues in which sampling data are important may include cleanup cost recovery, identification of pollution sources and responsible parties, and technical validation of remedial design methodologies. Because of the potential for involvement in legal actions, strict adherence to technical and administrative SOPs is essential during both the development and implementation of sampling activities.

Technically valid sampling begins with thorough planning and continues through the sample collection and analytical procedures. Administrative requirements involve thorough, accurate

documentation of all sampling activities. Documentation requirements include maintenance of a chain of custody, as well as accurate records of field activities and analytical instructions. Failure to observe these procedures fully and consistently may result in data that are questionable, invalid and non-defensible in court, and the consequent loss of enforcement proceedings.

8.0 CALCULATIONS

Refer to the specific SOPs for any calculations which are associated with sampling techniques.

9.0 QUALITY ASSURANCE/ QUALITY CONTROL

Refer to the specific SOPs for the type and frequency of QA/QC samples to be analyzed, the acceptance criteria for the QA/QC samples, and any other QA/QC activities which are associated with sampling techniques.

10.0 DATA VALIDATION

Refer to the specific SOPs for data validation activities that are associated with sampling techniques.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OSHA, and corporate health and safety procedures.



SAMPLING EQUIPMENT DECONTAMINATION

SOP#: 2006
DATE: 08/11/94
REV. #: 0.0

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to provide a description of the methods used for preventing, minimizing, or limiting cross-contamination of samples due to inappropriate or inadequate equipment decontamination and to provide general guidelines for developing decontamination procedures for sampling equipment to be used during hazardous waste operations as per 29 Code of Federal Regulations (CFR) 1910.120. This SOP does not address personnel decontamination.

These are standard (i.e. typically applicable) operating procedures which may be varied or changed as required, dependent upon site conditions, equipment limitation, or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

Mention of trade names or commercial products does not constitute U.S. Environmental Protection Agency (U.S. EPA) endorsement or recommendation for use.

2.0 METHOD SUMMARY

Removing or neutralizing contaminants from equipment minimizes the likelihood of sample cross contamination, reduces or eliminates transfer of contaminants to clean areas, and prevents the mixing of incompatible substances.

Gross contamination can be removed by physical decontamination procedures. These abrasive and non-abrasive methods include the use of brushes, air and wet blasting, and high and low pressure water cleaning.

The first step, a soap and water wash, removes all visible particulate matter and residual oils and grease. This may be preceded by a steam or high pressure

water wash to facilitate residuals removal. The second step involves a tap water rinse and a distilled/deionized water rinse to remove the detergent. An acid rinse provides a low pH media for trace metals removal and is included in the decontamination process if metal samples are to be collected. It is followed by another distilled/deionized water rinse. If sample analysis does not include metals, the acid rinse step can be omitted. Next, a high purity solvent rinse is performed for trace organics removal if organics are a concern at the site. Typical solvents used for removal of organic contaminants include acetone, hexane, or water. Acetone is typically chosen because it is an excellent solvent, miscible in water, and not a target analyte on the Priority Pollutant List. If acetone is known to be a contaminant of concern at a given site or if Target Compound List analysis (which includes acetone) is to be performed, another solvent may be substituted. The solvent must be allowed to evaporate completely and then a final distilled/deionized water rinse is performed. This rinse removes any residual traces of the solvent.

The decontamination procedure described above may be summarized as follows:

1. Physical removal
2. Non-phosphate detergent wash
3. Tap water rinse
4. Distilled/deionized water rinse
5. 10% nitric acid rinse
6. Distilled/deionized water rinse
7. Solvent rinse (pesticide grade)
8. Air dry
9. Distilled/deionized water rinse

If a particular contaminant fraction is not present at the site, the nine (9) step decontamination procedure specified above may be modified for site specificity. For example, the nitric acid rinse may be eliminated if metals are not of concern at a site. Similarly, the solvent rinse may be eliminated if organics are not of

concern at a site. Modifications to the standard procedure should be documented in the site specific work plan or subsequent report.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

The amount of sample to be collected and the proper sample container type (i.e., glass, plastic), chemical preservation, and storage requirements are dependent on the matrix being sampled and the parameter(s) of interest.

More specifically, sample collection and analysis of decontamination waste may be required before beginning proper disposal of decontamination liquids and solids generated at a site. This should be determined prior to initiation of site activities.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

- C The use of distilled/deionized water commonly available from commercial vendors may be acceptable for decontamination of sampling equipment provided that it has been verified by laboratory analysis to be analyte free (specifically for the contaminants of concern).
- C The use of an untreated potable water supply is not an acceptable substitute for tap water. Tap water may be used from any municipal or industrial water treatment system.
- C If acids or solvents are utilized in decontamination they raise health and safety, and waste disposal concerns.
- C Damage can be incurred by acid and solvent washing of complex and sophisticated sampling equipment.

5.0 EQUIPMENT/APPARATUS

Decontamination equipment, materials, and supplies are generally selected based on availability. Other considerations include the ease of decontaminating or disposing of the equipment. Most equipment and supplies can be easily procured. For example, soft-

bristle scrub brushes or long-handled bottle brushes can be used to remove contaminants. Large galvanized wash tubs, stock tanks, or buckets can hold wash and rinse solutions. Children's wading pools can also be used. Large plastic garbage cans or other similar containers lined with plastic bags can help segregate contaminated equipment. Contaminated liquid can be stored temporarily in metal or plastic cans or drums.

The following standard materials and equipment are recommended for decontamination activities:

5.1 Decontamination Solutions

- C Non-phosphate detergent
- C Selected solvents (acetone, hexane, nitric acid, etc.)
- C Tap water
- C Distilled or deionized water

5.2 Decontamination Tools/Supplies

- C Long and short handled brushes
- C Bottle brushes
- C Drop cloth/plastic sheeting
- C Paper towels
- C Plastic or galvanized tubs or buckets
- C Pressurized sprayers (H₂O)
- C Solvent sprayers
- C Aluminum foil

5.3 Health and Safety Equipment

Appropriate personal protective equipment (i.e., safety glasses or splash shield, appropriate gloves, aprons or coveralls, respirator, emergency eye wash)

5.4 Waste Disposal

- C Trash bags
- C Trash containers
- C 55-gallon drums
- C Metal/plastic buckets/containers for storage and disposal of decontamination solutions

6.0 REAGENTS

There are no reagents used in this procedure aside from the actual decontamination solutions. Table 1 (Appendix A) lists solvent rinses which may be required for elimination of particular chemicals. In

general, the following solvents are typically utilized for decontamination purposes:

- C 10% nitric acid is typically used for inorganic compounds such as metals. An acid rinse may not be required if inorganics are not a contaminant of concern.
- C Acetone (pesticide grade)⁽¹⁾
- C Hexane (pesticide grade)⁽¹⁾
- C Methanol⁽¹⁾

⁽¹⁾ - Only if sample is to be analyzed for organics.

7.0 PROCEDURES

As part of the health and safety plan, a decontamination plan should be developed and reviewed. The decontamination line should be set up before any personnel or equipment enter the areas of potential exposure. The equipment decontamination plan should include:

- C The number, location, and layout of decontamination stations.
- C Decontamination equipment needed.
- C Appropriate decontamination methods.
- C Methods for disposal of contaminated clothing, equipment, and solutions.
- C Procedures can be established to minimize the potential for contamination. This may include: (1) work practices that minimize contact with potential contaminants; (2) using remote sampling techniques; (3) covering monitoring and sampling equipment with plastic, aluminum foil, or other protective material; (4) watering down dusty areas; (5) avoiding laying down equipment in areas of obvious contamination; and (6) use of disposable sampling equipment.

7.1 Decontamination Methods

All samples and equipment leaving the contaminated area of a site must be decontaminated to remove any contamination that may have adhered to equipment. Various decontamination methods will remove contaminants by: (1) flushing or other physical action, or (2) chemical complexing to inactivate

contaminants by neutralization, chemical reaction, disinfection, or sterilization.

Physical decontamination techniques can be grouped into two categories: abrasive methods and non-abrasive methods, as follows:

7.1.1 Abrasive Cleaning Methods

Abrasive cleaning methods work by rubbing and wearing away the top layer of the surface containing the contaminant. The mechanical abrasive cleaning methods are most commonly used at hazardous waste sites. The following abrasive methods are available:

Mechanical

Mechanical methods of decontamination include using metal or nylon brushes. The amount and type of contaminants removed will vary with the hardness of bristles, length of time brushed, degree of brush contact, degree of contamination, nature of the surface being cleaned, and degree of contaminant adherence to the surface.

Air Blasting

Air blasting equipment uses compressed air to force abrasive material through a nozzle at high velocities. The distance between nozzle and surface cleaned, air pressure, time of application, and angle at which the abrasive strikes the surface will dictate cleaning efficiency. Disadvantages of this method are the inability to control the amount of material removed and the large amount of waste generated.

Wet Blasting

Wet blast cleaning involves use of a suspended fine abrasive. The abrasive/water mixture is delivered by compressed air to the contaminated area. By using a very fine abrasive, the amount of materials removed can be carefully controlled.

7.1.2 Non-Abrasive Cleaning Methods

Non-abrasive cleaning methods work by forcing the contaminant off a surface with pressure. In general, the equipment surface is not removed using non-abrasive methods.

Low-Pressure Water

This method consists of a container which is filled with water. The user pumps air out of the container to create a vacuum. A slender nozzle and hose allow the user to spray in hard-to-reach places.

High-Pressure Water

This method consists of a high-pressure pump, an operator controlled directional nozzle, and a high-pressure hose. Operating pressure usually ranges from 340 to 680 atmospheres (atm) and flow rates usually range from 20 to 140 liters per minute.

Ultra-High-Pressure Water

This system produces a water jet that is pressured from 1,000 to 4,000 atmospheres. This ultra-high-pressure spray can remove tightly-adhered surface films. The water velocity ranges from 500 meters/second (m/s) (1,000 atm) to 900 m/s (4,000 atm). Additives can be used to enhance the cleaning action.

Rinsing

Contaminants are removed by rinsing through dilution, physical attraction, and solubilization.

Damp Cloth Removal

In some instances, due to sensitive, non-waterproof equipment or due to the unlikelihood of equipment being contaminated, it is not necessary to conduct an extensive decontamination procedure. For example, air sampling pumps hooked on a fence, placed on a drum, or wrapped in plastic bags are not likely to become heavily contaminated. A damp cloth should be used to wipe off contaminants which may have adhered to equipment through airborne contaminants or from surfaces upon which the equipment was set.

Disinfection/Sterilization

Disinfectants are a practical means of inactivating infectious agents. Unfortunately, standard sterilization methods are impractical for large equipment. This method of decontamination is typically performed off-site.

7.2 Field Sampling Equipment Decontamination Procedures

The decontamination line is setup so that the first station is used to clean the most contaminated item. It progresses to the last station where the least contaminated item is cleaned. The spread of contaminants is further reduced by separating each decontamination station by a minimum of three (3) feet. Ideally, the contamination should decrease as the equipment progresses from one station to another farther along in the line.

A site is typically divided up into the following boundaries: Hot Zone or Exclusion Zone (EZ), the Contamination Reduction Zone (CRZ), and the Support or Safe Zone (SZ). The decontamination line should be setup in the Contamination Reduction Corridor (CRC) which is in the CRZ. Figure 1 (Appendix B) shows a typical contaminant reduction zone layout. The CRC controls access into and out of the exclusion zone and confines decontamination activities to a limited area. The CRC boundaries should be conspicuously marked. The far end is the hotline, the boundary between the exclusion zone and the contamination reduction zone. The size of the decontamination corridor depends on the number of stations in the decontamination process, overall dimensions of the work zones, and amount of space available at the site. Whenever possible, it should be a straight line.

Anyone in the CRC should be wearing the level of protection designated for the decontamination crew. Another corridor may be required for the entry and exit of heavy equipment. Sampling and monitoring equipment and sampling supplies are all maintained outside of the CRC. Personnel don their equipment away from the CRC and enter the exclusion zone through a separate access control point at the hotline. One person (or more) dedicated to decontaminating equipment is recommended.

7.2.1 Decontamination Setup

Starting with the most contaminated station, the decontamination setup should be as follows:

Station 1: Segregate Equipment Drop

Place plastic sheeting on the ground (Figure 2, Appendix B). Size will depend on amount of

equipment to be decontaminated. Provide containers lined with plastic if equipment is to be segregated. Segregation may be required if sensitive equipment or mildly contaminated equipment is used at the same time as equipment which is likely to be heavily contaminated.

Station 2: Physical Removal With A High-Pressure Washer (Optional)

As indicated in 7.1.2, a high-pressure wash may be required for compounds which are difficult to remove by washing with brushes. The elevated temperature of the water from the high-pressure washers is excellent at removing greasy/oily compounds. High pressure washers require water and electricity.

A decontamination pad may be required for the high-pressure wash area. An example of a wash pad may consist of an approximately 1 1/2 foot-deep basin lined with plastic sheeting and sloped to a sump at one corner. A layer of sand can be placed over the plastic and the basin is filled with gravel or shell. The sump is also lined with visqueen and a barrel is placed in the hole to prevent collapse. A sump pump is used to remove the water from the sump for transfer into a drum.

Typically heavy machinery is decontaminated at the end of the day unless site sampling requires that the machinery be decontaminated frequently. A separate decontamination pad may be required for heavy equipment.

Station 3: Physical Removal With Brushes And A Wash Basin

Prior to setting up Station 3, place plastic sheeting on the ground to cover areas under Station 3 through Station 10.

Fill a wash basin, a large bucket, or child's swimming pool with non-phosphate detergent and tap water. Several bottle and bristle brushes to physically remove contamination should be dedicated to this station. Approximately 10 - 50 gallons of water may be required initially depending upon the amount of equipment to decontaminate and the amount of gross contamination.

Station 4: Water Basin

Fill a wash basin, a large bucket, or child's swimming

pool with tap water. Several bottle and bristle brushes should be dedicated to this station. Approximately 10-50 gallons of water may be required initially depending upon the amount of equipment to decontaminate and the amount of gross contamination.

Station 5: Low-Pressure Sprayers

Fill a low-pressure sprayer with distilled/deionized water. Provide a 5-gallon bucket or basin to contain the water during the rinsing process. Approximately 10-20 gallons of water may be required initially depending upon the amount of equipment to decontaminate and the amount of gross contamination.

Station 6: Nitric Acid Sprayers

Fill a spray bottle with 10% nitric acid. An acid rinse may not be required if inorganics are not a contaminant of concern. The amount of acid will depend on the amount of equipment to be decontaminated. Provide a 5-gallon bucket or basin to collect acid during the rinsing process.

Station 7: Low-Pressure Sprayers

Fill a low-pressure sprayer with distilled/deionized water. Provide a 5-gallon bucket or basin to collect water during the rinsate process.

Station 8: Organic Solvent Sprayers

Fill a spray bottle with an organic solvent. After each solvent rinse, the equipment should be rinsed with distilled/deionized water and air dried. Amount of solvent will depend on the amount of equipment to decontaminate. Provide a 5-gallon bucket or basin to collect the solvent during the rinsing process.

Solvent rinses may not be required unless organics are a contaminant of concern, and may be eliminated from the station sequence.

Station 9: Low-Pressure Sprayers

Fill a low-pressure sprayer with distilled/deionized water. Provide a 5-gallon bucket or basin to collect water during the rinsate process.

Station 10: Clean Equipment Drop

Lay a clean piece of plastic sheeting over the bottom

plastic layer. This will allow easy removal of the plastic in the event that it becomes dirty. Provide aluminum foil, plastic, or other protective material to wrap clean equipment.

7.2.2 Decontamination Procedures

Station 1: Segregate Equipment Drop

Deposit equipment used on-site (i.e., tools, sampling devices and containers, monitoring instruments radios, clipboards, etc.) on the plastic drop cloth/sheet or in different containers with plastic liners. Each will be contaminated to a different degree. Segregation at the drop reduces the probability of cross contamination. Loose leaf sampling data sheets or maps can be placed in plastic zip lock bags if contamination is evident.

Station 2: Physical Removal With A High-Pressure Washer (Optional)

Use high pressure wash on grossly contaminated equipment. Do not use high- pressure wash on sensitive or non-waterproof equipment.

Station 3: Physical Removal With Brushes And A Wash Basin

Scrub equipment with soap and water using bottle and bristle brushes. Only sensitive equipment (i.e., radios, air monitoring and sampling equipment) which is waterproof should be washed. Equipment which is not waterproof should have plastic bags removed and wiped down with a damp cloth. Acids and organic rinses may also ruin sensitive equipment. Consult the manufacturers for recommended decontamination solutions.

Station 4: Equipment Rinse

Wash soap off of equipment with water by immersing the equipment in the water while brushing. Repeat as many times as necessary.

Station 5: Low-Pressure Rinse

Rinse sampling equipment with distilled/deionized water with a low-pressure sprayer.

Station 6: Nitric Acid Sprayers (required only if metals are a contaminant of concern)

Using a spray bottle rinse sampling equipment with nitric acid. Begin spraying (inside and outside) at one end of the equipment allowing the acid to drip to the other end into a 5-gallon bucket. A rinsate blank may be required at this station. Refer to Section 9.

Station 7: Low-Pressure Sprayers

Rinse sampling equipment with distilled/deionized water with a low-pressure sprayer.

Station 8: Organic Solvent Sprayers

Rinse sampling equipment with a solvent. Begin spraying (inside and outside) at one end of the equipment allowing the solvent to drip to the other end into a 5-gallon bucket. Allow the solvent to evaporate from the equipment before going to the next station. A QC rinsate sample may be required at this station.

Station 9: Low-Pressure Sprayers

Rinse sampling equipment with distilled/deionized water with a low-pressure washer.

Station 10: Clean Equipment Drop

Lay clean equipment on plastic sheeting. Once air dried, wrap sampling equipment with aluminum foil, plastic, or other protective material.

7.2.3 Post Decontamination Procedures

1. Collect high-pressure pad and heavy equipment decontamination area liquid and waste and store in appropriate drum or container. A sump pump can aid in the collection process. Refer to the Department of Transportation (DOT) requirements for appropriate containers based on the contaminant of concern.
2. Collect high-pressure pad and heavy equipment decontamination area solid waste and store in appropriate drum or container. Refer to the DOT requirements for appropriate containers based on the contaminant of concern.
3. Empty soap and water liquid wastes from basins and buckets and store in appropriate

minimum of 4 feet high.

14. All monitor wells should be labelled and dated with paint or steel tags.

7.4 Well Development

Well development is the process by which the aquifer's hydraulic conductivity is restored by removing drilling fluids, and fine-grained formation material from newly installed wells. Two methods of well development that are commonly used are surging and bailing, and overpumping. A well is considered developed when the pH and conductivity of the groundwater stabilizes and the measured turbidity is <50 nephelometric turbidity units (NTUs).

Surging and bailing will be performed as follows:

1. Measure the total depth (TD) of the well and depth to water (DTW).
2. Using an appropriately sized surge block, surge 5-foot sections of well screen, using 10-20 up/down cycles per section. Periodically remove the surge block and bail accumulated sediment from the well, as required.
3. For open-hole wells, a 6-inch surge block will be used inside the cased portion of the well. Sediments will be bailed periodically, as required. Overpumping may be used in combination with surging and bailing for development of bedrock wells. The method(s) used will be based on field conditions encountered, and will be determined by the site hydrogeologist. However, sediment will initially be removed from the wells by bailing in order to minimize the volume of development water generated.

The pump used must be rated to achieve the desired yield at a given depth. The pump system should include the following:

- C A check valve to prevent water from running back into the well when the pump is shut off
- C Flexible discharge hose
- C Safety cable or rope to remove the pump from the well

- C Flow meter monitoring system (measuring bucket or inline flow meter)
- C Generator
- C Amp meter, to measure electrical current (load)

The amp meter is used to monitor pump performance. If the pump becomes clogged, the current will increase due to stress on the pump. If the water level drops below the intake ports, the current will drop due to decreased resistance on the pump.

8.0 CALCULATIONS

To maintain an open borehole during rotary drilling, the drilling fluid must exert a pressure greater than the formation pore pressure. Typical pore pressures for unconfined and confined aquifers are 0.433 define (psi/ft) and 0.465 psi/ft, respectively.

The relationship for determining the hydrostatic pressure of the drilling fluid is:

$$\text{Hydrostatic Pressure (psi)} = \text{Fluid Density (lb/gal)} \times \text{Height of Fluid Column (ft)} \times 0.052$$

The minimum grout volume necessary to grout a well can be calculated using:

$$\text{Grout Vol (ft}^3\text{)} = \text{Vol of Borehole (ft}^3\text{)} - \text{Vol of Casing (ft}^3\text{)} = L (r_B^2 - r_C^2)$$

where:

- L = length of borehole to be grouted (ft)
- r_B = radius of boring (ft)
- r_C = radius of casing (ft)

9.0 QUALITY ASSURANCE/ QUALITY CONTROL

There are no specific quality assurance activities that apply to the implementation of these procedures. However, the following general QA procedures apply:

1. All data must be documented on standard well completion forms, field data sheets or within field/site logbooks. Descriptive logs, pump tests, and well completion data are entered on Geolis® forms. The Geolis® forms are used to ensure data is collected uniformly by all Site Geologists and provide

input to a standardized computer well file. Appendix A contains examples of Geolis® forms used to record descriptions of geologic samples.

2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation and must be documented.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

Drilling rigs and equipment present a variety of safety hazards. REAC personnel working around drilling rigs should know the position of the emergency "kill" switch. Wirelines and ropes should be inspected and frayed or damaged sections discarded. Swivels and blocks should turn freely. Gages should be operational and controls clearly marked. All underground utilities should be clearly marked, and drillers should be aware of any overhead hazards such as power lines. Avoid drilling in these areas. Ear protection should be worn when working around drilling equipment for extended periods of time, particularly air rotary equipment. Failure to follow safety procedure or wear the proper personal protection gear on the part of either the drilling crew or REAC personnel may result in dismissal from the job.

When working with potentially hazardous materials, follow U.S. EPA, OSHA, and corporate health and safety practices.

12.0 REFERENCES

- American Society for Testing and Materials. 1991. Annual Book of ASTM Standards. Designation: D5092-90 Standard Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers. p. 1081-1092. Philadelphia, PA.
- Boateng, K., P.C. Evens, and S.M. Testa. 1984. "Groundwater Contamination of Two Production Wells: A Case History." *Groundwater Monitoring Review*, V.4, No. 2, p. 24-31.
- Keely, J.F. and Kwasi Boateng. 1987. "Monitoring Well Installation, Purging, and Sampling Techniques - Part 1: Conceptualizations." *Groundwater* V. 25, No. 3, p. 300-313.
- Keely, J.F. and Kwasi Boateng. 1987. "Monitoring Well Installation, Purging, and Sampling Techniques - Part 2: Case Histories." *Groundwater* V. 25, No. 4, p. 427-439.
- Driscoll, F.G. 1986. *Groundwater and Wells* (2nd ed.): Johnson Division, UOP Inc., St. Paul, MN. p. 1089
- U.S. EPA. 1987. A Compendium of Superfund Field Operations Methods. EPA/540/p-87/001 Office of Emergency and Remedial Responses. Washington, DC.

APPENDIX A

Table

Table 1. Soluble Contaminants and Recommended Solvent Rinse

TABLE 1 Soluble Contaminants and Recommended Solvent Rinse		
SOLVENT ⁽¹⁾	EXAMPLES OF SOLVENTS	SOLUBLE CONTAMINANTS
Water	Deionized water Tap water	Low-chain hydrocarbons Inorganic compounds Salts Some organic acids and other polar compounds
Dilute Acids	Nitric acid Acetic acid Boric acid	Basic (caustic) compounds (e.g., amines and hydrazines)
Dilute Bases	Sodium bicarbonate (e.g., soap detergent)	Acidic compounds Phenol Thiols Some nitro and sulfonic compounds
Organic Solvents ⁽²⁾	Alcohols Ethers Ketones Aromatics Straight chain alkalines (e.g., hexane) Common petroleum products (e.g., fuel, oil, kerosene)	Nonpolar compounds (e.g., some organic compounds)
Organic Solvent ⁽²⁾	Hexane	PCBs

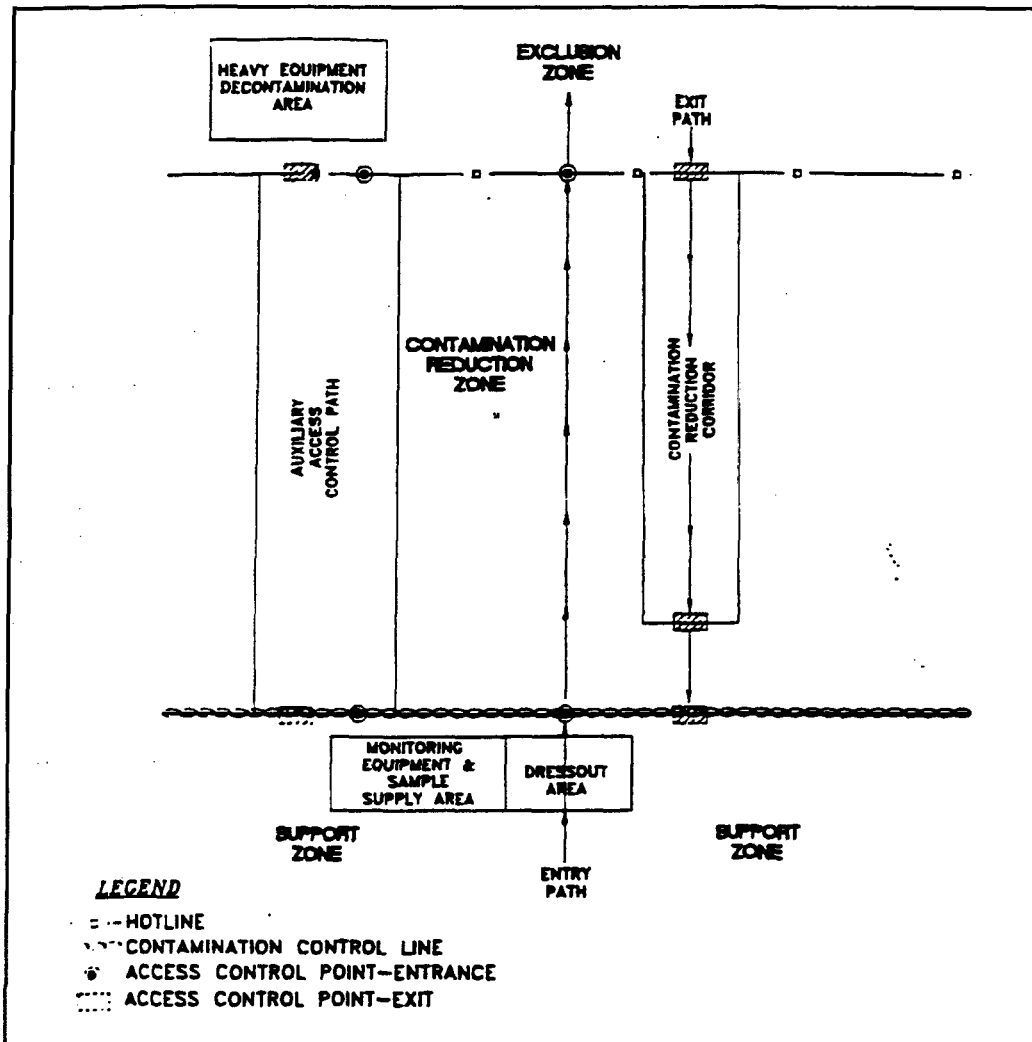
⁽¹⁾ - Material safety data sheets are required for all decontamination solvents or solutions as required by the Hazard Communication Standard

⁽²⁾ - WARNING: Some organic solvents can permeate and/or degrade the protective clothing

APPENDIX B

Figures

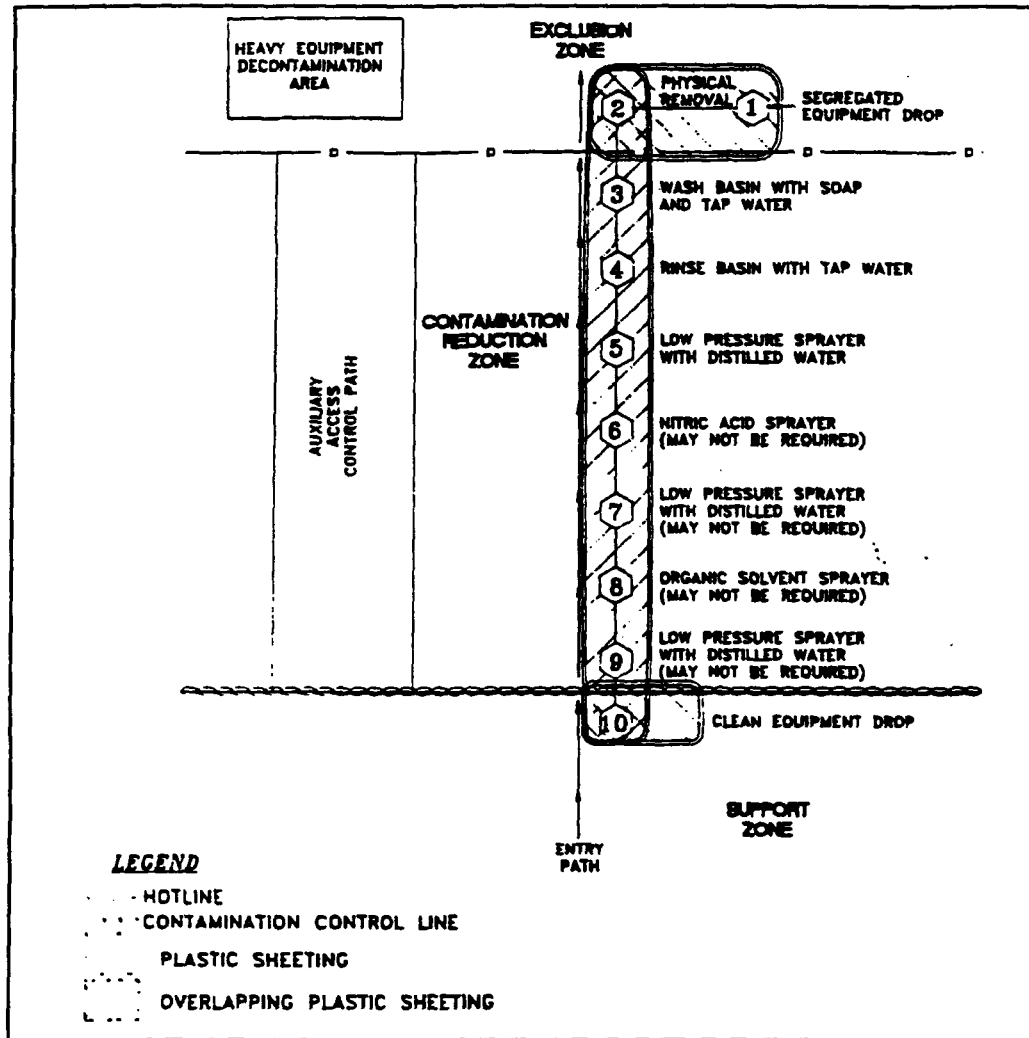
Figure 1. Contamination Reduction Zone Layout



APPENDIX B (Cont'd.)

Figures

Figure 2. Decontamination Layout





U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2012
PAGE: 1 of 13
REV: 0.0
DATE: 02/18/00

SOIL SAMPLING

CONTENTS

- 1.0 SCOPE AND APPLICATION
- 2.0 METHOD SUMMARY
- 3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE
- 4.0 POTENTIAL PROBLEMS
- 5.0 EQUIPMENT
- 6.0 REAGENTS
- 7.0 PROCEDURES
 - 7.1 Preparation
 - 7.2 Sample Collection
 - 7.2.1 Surface Soil Samples
 - 7.2.2 Sampling at Depth with Augers and Thin Wall Tube Samplers
 - 7.2.3 Sampling at Depth with a Trier
 - 7.2.4 Sampling at Depth with a Split Spoon (Barrel) Sampler
 - 7.2.5 Test Pit/Trench Excavation
- 8.0 CALCULATIONS
- 9.0 QUALITY ASSURANCE/QUALITY CONTROL
- 10.0 DATA VALIDATION
- 11.0 HEALTH AND SAFETY
- 12.0 REFERENCES
- 13.0 APPENDIX
 - Figures



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2012
PAGE: 2 of 13
REV: 0.0
DATE: 02/18/00

SOIL SAMPLING

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to describe the procedures for the collection of representative soil samples. Sampling depths are assumed to be those that can be reached without the use of a drill rig, direct-push, or other mechanized equipment (except for a back-hoe). Analysis of soil samples may determine whether concentrations of specific pollutants exceed established action levels, or if the concentrations of pollutants present a risk to public health, welfare, or the environment.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent upon site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the actual procedures used should be documented and described in an appropriate site report.

Mention of trade names or commercial products does not constitute U.S. Environmental Protection Agency (EPA) endorsement or recommendation for use.

2.0 METHOD SUMMARY

Soil samples may be collected using a variety of methods and equipment depending on the depth of the desired sample, the type of sample required (disturbed vs. undisturbed), and the soil type. Near-surface soils may be easily sampled using a spade, trowel, and scoop. Sampling at greater depths may be performed using a hand auger, continuous flight auger, a trier, a split-spoon, or, if required, a backhoe.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

Chemical preservation of solids is not generally recommended. Samples should, however, be cooled and protected from sunlight to minimize any potential reaction. The amount of sample to be collected and proper sample container type are discussed in ERT/REAC SOP #2003 Rev. 0.0 08/11/94, *Sample Storage, Preservation and Handling*.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

There are two primary potential problems associated with soil sampling - cross contamination of samples and improper sample collection. Cross contamination problems can be eliminated or minimized through the use of dedicated sampling equipment. If this is not possible or practical, then decontamination of sampling equipment is necessary. Improper sample collection can involve using contaminated equipment, disturbance of the matrix resulting in compaction of the sample, or inadequate homogenization of the samples where required, resulting in variable, non-representative results.

5.0 EQUIPMENT



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2012
PAGE: 3 of 13
REV: 0.0
DATE: 02/18/00

SOIL SAMPLING

Soil sampling equipment includes the following:

- ☐ Maps/plot plan
- ☐ Safety equipment, as specified in the site-specific Health and Safety Plan
- ☐ Survey equipment or global positioning system (GPS) to locate sampling points
- ☐ Tape measure
- ☐ Survey stakes or flags
- ☐ Camera and film
- ☐ Stainless steel, plastic, or other appropriate homogenization bucket, bowl or pan
- ☐ Appropriate size sample containers
- ☐ Ziplock plastic bags
- ☐ Logbook
- ☐ Labels
- ☐ Chain of Custody records and custody seals
- ☐ Field data sheets and sample labels
- ☐ Cooler(s)
- ☐ Ice
- ☐ Vermiculite
- ☐ Decontamination supplies/equipment
- ☐ Canvas or plastic sheet
- ☐ Spade or shovel
- ☐ Spatula
- ☐ Scoop
- ☐ Plastic or stainless steel spoons
- ☐ Trowel(s)
- ☐ Continuous flight (screw) auger
- ☐ Bucket auger
- ☐ Post hole auger
- ☐ Extension rods
- ☐ T-handle
- ☐ Sampling trier
- ☐ Thin wall tube sampler
- ☐ Split spoons
- ☐ Vehimeyer soil sampler outfit
 - Tubes
 - Points
 - Drive head
 - Drop hammer
 - Puller jack and grip
- ☐ Backhoe

6.0 REAGENTS



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2012
PAGE: 4 of 13
REV: 0.0
DATE: 02/18/00

SOIL SAMPLING

Reagents are not used for the preservation of soil samples. Decontamination solutions are specified in ERT/REAC SOP #2006 Rev. 0.0 08/11/94, *Sampling Equipment Decontamination*, and the site specific work plan.

7.0 PROCEDURES

7.1 Preparation

1. Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies required.
2. Obtain necessary sampling and monitoring equipment.
3. Decontaminate or pre-clean equipment, and ensure that it is in working order.
4. Prepare schedules and coordinate with staff, client, and regulatory agencies, if appropriate.
5. Perform a general site survey prior to site entry in accordance with the site specific Health and Safety Plan.
6. Use stakes, flagging, or buoys to identify and mark all sampling locations. Specific site factors, including extent and nature of contaminant, should be considered when selecting sample location. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions. All staked locations should be utility-cleared by the property owner or the On-Scene-Coordinator (OSC) prior to soil sampling; and utility clearance should always be confirmed before beginning work.

7.2 Sample Collection

7.2.1 Surface Soil Samples

Collection of samples from near-surface soil can be accomplished with tools such as spades, shovels, trowels, and scoops. Surface material is removed to the required depth and a stainless steel or plastic scoop is then used to collect the sample.

This method can be used in most soil types but is limited to sampling at or near the ground surface. Accurate, representative samples can be collected with this procedure depending on the care and precision demonstrated by the sample team member. A flat, pointed mason trowel to cut a block of the desired soil is helpful when undisturbed profiles are required. Tools plated with chrome or other materials should not be used. Plating is particularly common with garden implements such as potting trowels.

The following procedure is used to collect surface soil samples:



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2012
PAGE: 5 of 13
REV: 0.0
DATE: 02/18/00

SOIL SAMPLING

1. Carefully remove the top layer of soil or debris to the desired sample depth with a pre-cleaned spade.
2. Using a pre-cleaned, stainless steel scoop, plastic spoon, or trowel, remove and discard a thin layer of soil from the area which came in contact with the spade.
3. If volatile organic analysis is to be performed, transfer the sample directly into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval or location into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

7.2.2 Sampling at Depth with Augers and Thin Wall Tube Samplers

This system consists of an auger, or a thin-wall tube sampler, a series of extensions, and a "T" handle (Figure 1, Appendix A). The auger is used to bore a hole to a desired sampling depth, and is then withdrawn. The sample may be collected directly from the auger. If a core sample is to be collected, the auger tip is then replaced with a thin wall tube sampler. The system is then lowered down the borehole, and driven into the soil to the completion depth. The system is withdrawn and the core is collected from the thin wall tube sampler.

Several types of augers are available; these include: bucket type, continuous flight (screw), and post-hole augers. Bucket type augers are better for direct sample recovery because they provide a large volume of sample in a short time. When continuous flight augers are used, the sample can be collected directly from the flights. The continuous flight augers are satisfactory when a composite of the complete soil column is desired. Post-hole augers have limited utility for sample collection as they are designed to cut through fibrous, rooted, swampy soil and cannot be used below a depth of approximately three feet.

The following procedure is used for collecting soil samples with the auger:

1. Attach the auger bit to a drill rod extension, and attach the "T" handle to the drill rod.



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2012
PAGE: 6 of 13
REV: 0.0
DATE: 02/18/00

SOIL SAMPLING

2. Clear the area to be sampled of any surface debris (e.g., twigs, rocks, litter). It may be advisable to remove the first three to six inches of surface soil for an area approximately six inches in radius around the drilling location.
3. Begin augering, periodically removing and depositing accumulated soils onto a plastic sheet spread near the hole. This prevents accidental brushing of loose material back down the borehole when removing the auger or adding drill rods. It also facilitates refilling the hole, and avoids possible contamination of the surrounding area.
4. After reaching the desired depth, slowly and carefully remove the auger from the hole. When sampling directly from the auger, collect the sample after the auger is removed from the hole and proceed to Step 10.
5. Remove auger tip from the extension rods and replace with a pre-cleaned thin wall tube sampler. Install the proper cutting tip.
6. Carefully lower the tube sampler down the borehole. Gradually force the tube sampler into the soil. Do not scrape the borehole sides. Avoid hammering the rods as the vibrations may cause the boring walls to collapse.
7. Remove the tube sampler, and unscrew the drill rods.
8. Remove the cutting tip and the core from the device.
9. Discard the top of the core (approximately 1 inch), as this possibly represents material collected before penetration of the layer of concern. Place the remaining core into the appropriate labeled sample container. Sample homogenization is not required.
10. If volatile organic analysis is to be performed, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly.

When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2012
PAGE: 7 of 13
REV: 0.0
DATE: 02/18/00

SOIL SAMPLING

11. If another sample is to be collected in the same hole, but at a greater depth, reattach the auger bit to the drill and assembly, and follow steps 3 through 11, making sure to decontaminate the auger and tube sampler between samples.
12. Abandon the hole according to applicable state regulations. Generally, shallow holes can simply be backfilled with the removed soil material.

7.2.3 Sampling with a Trier

The system consists of a trier, and a "T" handle. The auger is driven into the soil to be sampled and used to extract a core sample from the appropriate depth.

The following procedure is used to collect soil samples with a sampling trier:

1. Insert the trier (Figure 2, Appendix A) into the material to be sampled at a 0° to 45° angle from horizontal. This orientation minimizes the spillage of sample.
2. Rotate the trier once or twice to cut a core of material.
3. Slowly withdraw the trier, making sure that the slot is facing upward.
4. If volatile organic analyses are required, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

7.2.4 Sampling at Depth with a Split Spoon (Barrel) Sampler

Split spoon sampling is generally used to collect undisturbed soil cores of 18 or 24 inches in length. A series of consecutive cores may be extracted with a split spoon sampler to give a complete soil column profile, or an auger may be used to drill down to the desired depth for sampling. The split spoon is then driven to its sampling depth through the bottom of the augured hole and the core extracted.

When split spoon sampling is performed to gain geologic information, all work should



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2012
PAGE: 8 of 13
REV: 0.0
DATE: 02/18/00

SOIL SAMPLING

be performed in accordance with ASTM D1586-98, "Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils".

The following procedures are used for collecting soil samples with a split spoon:

1. Assemble the sampler by aligning both sides of barrel and then screwing the drive shoe on the bottom and the head piece on top.
2. Place the sampler in a perpendicular position on the sample material.
3. Using a well ring, drive the tube. Do not drive past the bottom of the head piece or compression of the sample will result.
4. Record in the site logbook or on field data sheets the length of the tube used to penetrate the material being sampled, and the number of blows required to obtain this depth.
5. Withdraw the sampler, and open by unscrewing the bit and head and splitting the barrel. The amount of recovery and soil type should be recorded on the boring log. If a split sample is desired, a cleaned, stainless steel knife should be used to divide the tube contents in half, longitudinally. This sampler is typically available in 2 and 3 1/2 inch diameters. A larger barrel may be necessary to obtain the required sample volume.
6. Without disturbing the core, transfer it to appropriate labeled sample container(s) and seal tightly.

7.2.5 Test Pit/Trench Excavation

A backhoe can be used to remove sections of soil, when detailed examination of soil characteristics are required. This is probably the most expensive sampling method because of the relatively high cost of backhoe operation.

The following procedures are used for collecting soil samples from test pits or trenches:

1. Prior to any excavation with a backhoe, it is important to ensure that all sampling locations are clear of overhead and buried utilities.
2. Review the site specific Health & Safety plan and ensure that all safety precautions including appropriate monitoring equipment are installed as required.



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2012
PAGE: 9 of 13
REV: 0.0
DATE: 02/18/00

SOIL SAMPLING

3. Using the backhoe, excavate a trench approximately three feet wide and approximately one foot deep below the cleared sampling location. Place excavated soils on plastic sheets. Trenches greater than five feet deep must be sloped or protected by a shoring system, as required by OSHA regulations.
4. A shovel is used to remove a one to two inch layer of soil from the vertical face of the pit where sampling is to be done.
5. Samples are taken using a trowel, scoop, or coring device at the desired intervals. Be sure to scrape the vertical face at the point of sampling to remove any soil that may have fallen from above, and to expose fresh soil for sampling. In many instances, samples can be collected directly from the backhoe bucket.
6. If volatile organic analyses are required, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.
7. Abandon the pit or excavation according to applicable state regulations. Generally, shallow excavations can simply be backfilled with the removed soil material.

8.0 CALCULATIONS

This section is not applicable to this SOP.

9.0 QUALITY ASSURANCE/QUALITY CONTROL

There are no specific quality assurance (QA) activities which apply to the implementation of these procedures. However, the following QA procedures apply:

1. All data must be documented on field data sheets or within site logbooks.
2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2012
PAGE: 10 of 13
REV: 0.0
DATE: 02/18/00

SOIL SAMPLING

activities must occur prior to sampling/operation, and they must be documented.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OHSA and corporate health and safety procedures, in addition to the procedures specified in the site specific Health & Safety Plan..

12.0 REFERENCES

Mason, B.J. 1983. Preparation of Soil Sampling Protocol: Technique and Strategies. EPA-600/4-83-020.

Barth, D.S. and B.J. Mason. 1984. Soil Sampling Quality Assurance User's Guide. EPA-600/4-84-043.

U.S. Environmental Protection Agency. 1984 Characterization of Hazardous Waste Sites - A Methods Manual: Volume II. Available Sampling Methods, Second Edition. EPA-600/4-84-076.

de Vera, E.R., B.P. Simmons, R.D. Stephen, and D.L. Storm. 1980. Samplers and Sampling Procedures for Hazardous Waste Streams. EPA-600/2-80-018.

ASTM D 1586-98, ASTM Committee on Standards, Philadelphia, PA.



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2012
PAGE: 11 of 13
REV: 0.0
DATE: 02/18/00

SOIL SAMPLING

APPENDIX A
Figures
SOP #2012
February 2000



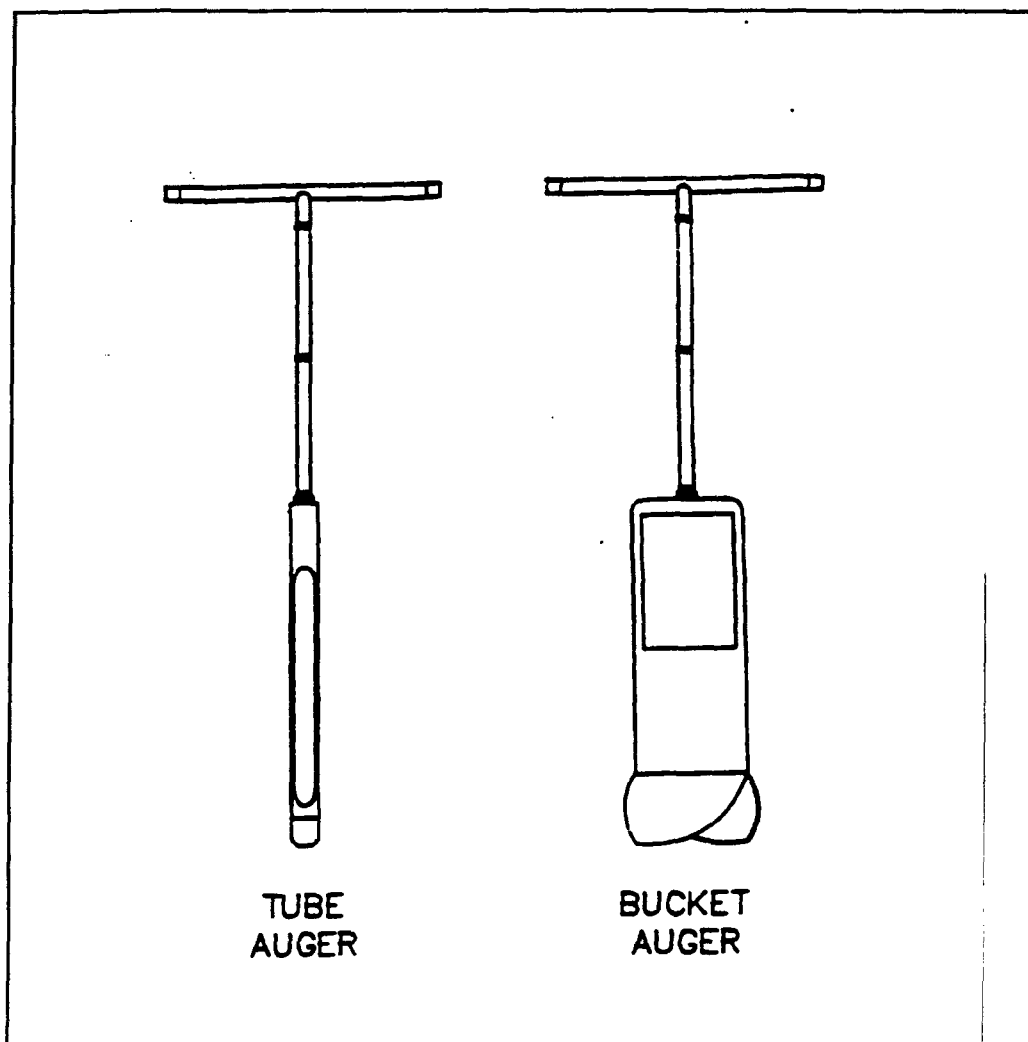
U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2012
PAGE: 12 of 13
REV: 0.0
DATE: 02/18/00

SOIL SAMPLING

FIGURE 1. Sampling Augers





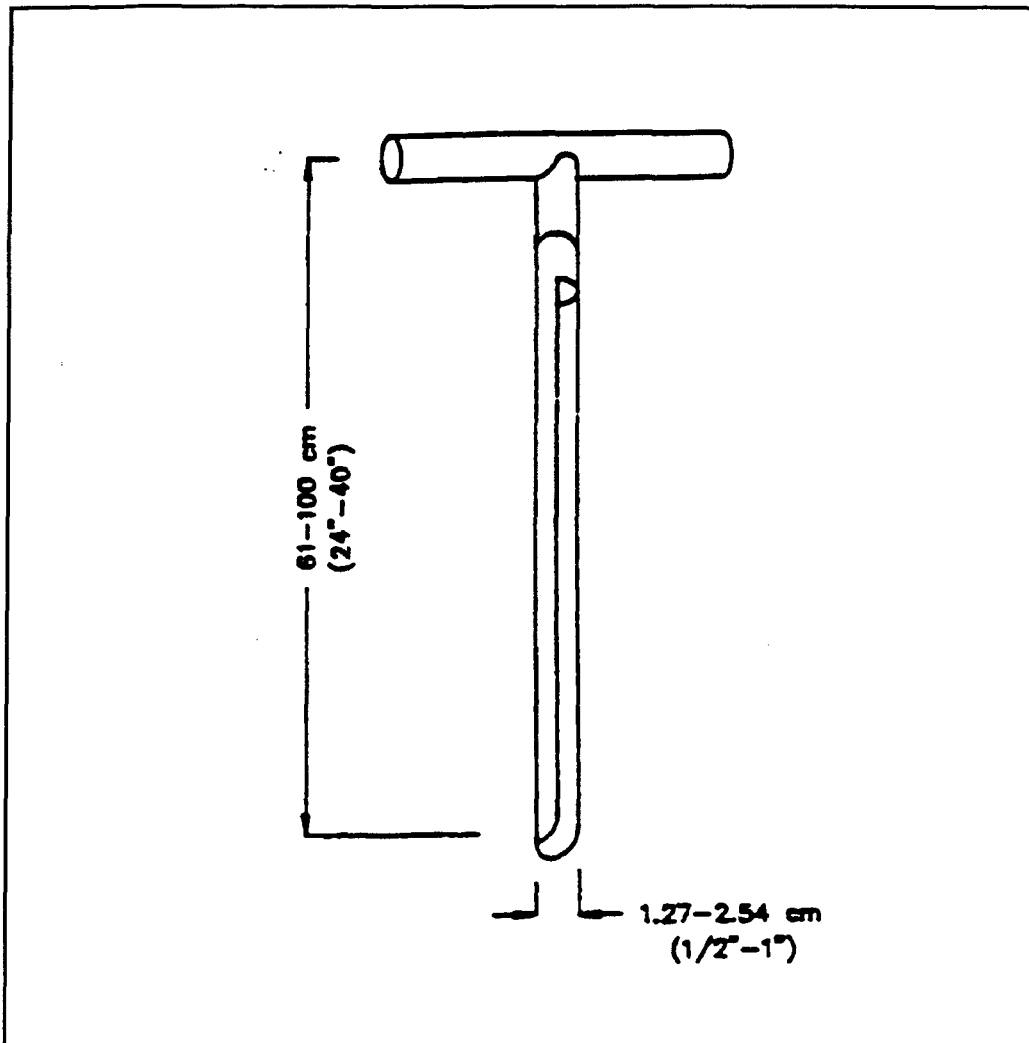
U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2012
PAGE: 13 of 13
REV: 0.0
DATE: 02/18/00

SOIL SAMPLING

FIGURE 2. Sampling Trier





U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2044
PAGE: 1 of 8
REV: 0.1
DATE: 10/23/01

MONITOR WELL DEVELOPMENT

CONTENTS

- 1.0 SCOPE AND APPLICATION*
- 2.0 METHOD SUMMARY*
- 3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE
- 4.0 INTERFERENCES AND POTENTIAL PROBLEMS*
- 5.0 EQUIPMENT/APPARATUS*
- 6.0 REAGENTS
- 7.0 PROCEDURES
 - 7.1 Preparation
 - 7.2 Operation*
 - 7.3 Post-Operation
- 8.0 CALCULATIONS*
- 9.0 QUALITY ASSURANCE/QUALITY CONTROL*
- 10.0 DATA VALIDATION
- 11.0 HEALTH AND SAFETY
- 12.0 REFERENCES*
- 13.0 APPENDICES*

*These sections affected by Revision 0.1.

SUPERCEDES: SOP #2044; Revision 0.0; 2/18/00; U.S. EPA Contract 68-C99-223.



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2044
PAGE: 2 of 8
REV: 0.1
DATE: 10/23/01

MONITOR WELL DEVELOPMENT

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to provide an overview of monitor well development practices. The purpose of monitor well development is to ensure removal of fine grained sediments (fines) from the vicinity of the well screen. This allows the water to flow freely from the formation into the well, and also reduces the turbidity of the water during sampling. The most common well development methods are: surging, jetting, overpumping, and bailing.

Surging involves raising and lowering a surge block or surge plunger inside the well. The resulting surging motion forces water into the formation and loosens sediment, pulled from the formation into the well. Occasionally, sediments must be removed from the well with a sand bailer to prevent sand locking of the surge block. This method may cause the sand pack around the screen to be displaced to a degree that damages its value as a filtering medium. Channels or voids may form near the screen if the filter pack sloughs away during surging (Keel and Boating, 1987).

Surging with compressed air is done by injecting a sudden charge of compressed air into the well with an air line so that water is forced through the well screen. The air is then turned off so that the water column falls back into the well and the process is repeated. Periodically, the air line is pulled up into a pipe string (educator) and water is pumped from the well using air as the lifting medium (air-lift pumping). The process is repeated until the well is sediment free. Method variations include leaving the air line in the pipe string at all times or using the well casing as the educator pipe.

Jetting involves lowering a small diameter pipe into the well and injecting a high velocity horizontal stream of water or air through the pipe into the screen openings. This method is especially effective at breaking down filter cakes developed during mud rotary drilling. Simultaneous air-lift pumping is usually used to remove fines.

Overpumping involves pumping at a rate rapid enough to draw the water level in the well as low as possible, and then allowing the well to recharge to the original level. This process is repeated until sediment-free water is produced.

Bailing includes the use of a simple manually operated check-valve bailer to remove water from the well. The bailing method, like other methods, should be repeated until sediment free water is produced. Bailing may be the method of choice in a shallow well or well that recharges slowly.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent on site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with a final report.

Mention of trade names or commercial products does not constitute United States Environmental Protection



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2044
PAGE: 3 of 8
REV: 0.1
DATE: 10/23/01

MONITOR WELL DEVELOPMENT

Agency (U.S. EPA) endorsement or recommendation for use.

2.0 METHOD SUMMARY

After installation, development of a well should occur as soon as it is practical. It should not occur any sooner than 48 hours after grouting is completed, especially if a vigorous well development method (i.e. surging) is being used. If a less vigorous method (i.e. bailing) is used, it may be initiated shortly after installation. The method used for development should not interfere with the setting of the well seal.

Several activities must take place prior to well development. First, open the monitor well, take initial measurements (i.e., head space air monitoring readings, water level, total depth of the well) and record results in the site logbook. Develop the well by the appropriate method to accommodate site conditions and project objectives. Continue until the development water is clear and free of sediments, or until parameters such as pH, temperature, and specific conductivity stabilize. Containerize all purge water from wells with known or suspected contamination. Record final measurements in the site logbook. Decontaminate equipment as appropriate prior to use in the next well.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

This section is not applicable to this SOP.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

The following problems may be associated with well development:

1. Overpumping is not as vigorous as surging and jetting, and is probably the most desirable method for monitor well development. The possibility of disturbing the filter pack is greatest with surging and jetting well development methods.
2. The introduction of external water or air by jetting may alter the hydro chemistry of the aquifer.
3. Surging with air may produce "air locking" in some formations, preventing water from flowing into the well.
4. The use of surge blocks in formations containing clay may cause plugging of the screen.
5. Small (2-inch nominal diameter) submersible pumps that will fit in 2-inch diameter well casing are especially susceptible to clogging if used in well development applications.
6. Chemicals/reagents used during the decontamination of drilling equipment may complicate well development.



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2044
PAGE: 4 of 8
REV: 0.1
DATE: 10/23/01

MONITOR WELL DEVELOPMENT

5.0 EQUIPMENT/APPARATUS

The type of equipment used for well development is dependent on the diameter of the well and the development method. For example, the diameter of most submersible pumps is too large to fit into a two-inch inner diameter (I.D.) well, and other development methods should be used. Obtaining the highest possible yield is not usually an objective in developing monitor wells and vigorous development is not always necessary. Many monitor wells are constructed in fine-grained formations that would not normally be considered aquifers. Specifications for the drilling contract should include the necessary well development equipment (air compressors, pumps, air lines, surge blocks, generators).

6.0 REAGENTS

The use of chemicals in developing wells that will be used to monitor groundwater quality should be avoided if possible; however, polyphosphates (a dispersing agent), acids, or disinfectants are often used in general well development. Polyphosphates should not be used in thinly bedded sequences of sands and clays. The use of decontamination solutions may also be necessary. If decontamination of equipment is required at a well, refer to Environmental Response Team/Response Engineering and Analytical Contract (ERT/REAC) SOP #2006, *Sampling Equipment Decontamination* and the site specific work plan.

7.0 PROCEDURES

7.1 Preparation

1. Coordinate site access and obtain keys to well locks.
2. Obtain information on each well to be developed (i.e., drilling method, well diameter, well depth, screened interval, anticipated contaminants).
3. Obtain a water level meter, a depth sounder, air monitoring instruments, materials for decontamination, and water quality instrumentation capable of measuring, at a minimum, pH, specific conductivity, temperature, and turbidity. Dissolved oxygen (DO) and salinity are also useful parameters.
4. Assemble containers for temporary storage of water produced during well development. Containers must be structurally sound, compatible with anticipated contaminants, and easy to manage in the field. The use of truck-mounted or roll-off tanks may be necessary in some cases; alternately, a portable water treatment unit (i.e., activated carbon) may be used to decontaminate the purge water.

7.2 Operation



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2044
PAGE: 5 of 8
REV: 0.1
DATE: 10/23/01

MONITOR WELL DEVELOPMENT

Development should be performed as soon as it is practical after the well is installed, but no sooner than 48 hours after well completion.

1. Assemble necessary equipment on a plastic sheet surrounding the well.
2. Record pertinent information in the site or personal logbook (personnel, time, location ID, etc.).
3. Open monitor well, take air monitor reading at the top of casing and in the breathing zone as appropriate.
4. Measure depth to water and the total depth of the monitor well. Calculate the water column volume of the well (Equation 1, Section 8.0).
5. Begin development and measure the initial pH, temperature, turbidity, and specific conductivity of the water and record in the site logbook. Note the initial color, clarity, and odor of the water.
6. Continue to develop the well and periodically measure the water quality parameters indicated in step 5 (above). Depending on project objectives and available time, development should proceed until these water quality parameters stabilize, or until the water has a turbidity of less than 50 nephelometric turbidity units (NTUs).
7. All water produced by development of contaminated or suspected contaminated wells must be containerized or treated. Each container must be clearly labeled with the location ID, date collected, and sampling contractor. Determination of the appropriate disposal method will be based on the analytical results from each well.
8. No water shall be added to the well to assist development without prior approval by the appropriate U.S. EPA ERT Work Assignment Manager (WAM) and/or appropriate state personnel. In some cases, small amounts of potable water may be added to help develop a poor yielding well. It is essential that at least five times the amount of water injected must be recovered from the well in order to assure that all injected water is removed from the formation.
9. Note the final water quality parameters in the site or personal logbook along with the following data:

Well designation (location ID)
Date(s) of well installation
Date(s) and time of well development



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2044
PAGE: 6 of 8
REV: 0.1
DATE: 10/23/01

MONITOR WELL DEVELOPMENT

Static water level before and after development
Quantity of water removed, and initial and completion time
Type and capacity of pump or bailer used
Description of well development techniques

7.3 Post-Operation

1. Decontaminate all equipment;
2. Secure holding tanks or containers of development water;
3. Review analytical results and determine the appropriate water disposal method. Actual disposal of the purge water is generally carried out by the On-Scene Coordinator (OSC).

8.0 CALCULATIONS

To calculate the volume of water in the well, the following equation is used:

$$\text{Well Volume (V)} = \pi^2 h (\text{cf}) \quad [\text{Equation 1}]$$

where:

π = pi (3.14)
 r = radius of monitoring well in feet (ft)
 h = height of the water column in ft. [This may be determined by subtracting the depth to water from the total depth of the well as measured from the same reference point.]
 cf = conversion factor in gallons per cubic foot (gal/ft^3) = $7.48 \text{ gal}/\text{ft}^3$. [In this equation, $7.48 \text{ gal}/\text{ft}^3$ is the necessary conversion factor.]

Monitor well diameters are typically 2-, 3-, 4-, or 6-inches. A number of standard conversion factors can be used to simplify the above equation using the diameter of the monitor well. The volume, in gallons per linear foot, for various standard monitor well diameters can be calculated as follows:

where:

$$V (\text{gal}/\text{ft}) = \pi^2 (\text{cf}) \quad [\text{Equation 2}]$$

π = pi
 r = radius of monitoring well (feet)
 cf = conversion factor ($7.48 \text{ gal}/\text{ft}^3$)



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2044
PAGE: 7 of 8
REV: 0.1
DATE: 10/23/01

MONITOR WELL DEVELOPMENT

For example, a two inch diameter well, the volume per linear foot can be calculated as follows:

$$\begin{aligned} V \text{ (gal/ft)} &= r^2 \text{ (cf)} \quad \text{[Equation 2]} \\ &= 3.14 (1/12 \text{ ft})^2 \cdot 7.48 \text{ gal/ft}^3 \\ &= 0.1631 \text{ gal/ft} \end{aligned}$$

NOTE: The diameter must be converted to the radius in feet as follows:

$$\frac{\text{Well Diameter (inches)}}{12} \times 0.5 = \text{Well Radius (feet)} \quad \text{[Equation 3]}$$

The volume in gallons/feet for the common size monitor wells are as follows:

Well diameter (inches)	2	3	4	6
Volume (gal/ft)	0.1631	0.3670	0.6524	1.4680

If you utilize the volumes for the common size wells above, Equation 1 is modified as follows:
where:

$$\text{Well volume} = (h)(f) \quad \text{[Equation 4]}$$

$$\begin{aligned} h &= \text{height of water column (feet)} \\ f &= \text{the volume in gal/ft calculated from Equation 2} \end{aligned}$$

9.0 QUALITY ASSURANCE/QUALITY CONTROL

There are no specific quality assurance activities, which apply to the implementation of these procedures. However, the following general quality assurance/quality control (QA/QC) procedures apply:

1. All data must be documented in site and/or personal logbooks.
2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation and must be documented.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2044
PAGE: 8 of 8
REV: 0.1
DATE: 10/23/01

MONITOR WELL DEVELOPMENT

When working with potentially hazardous materials, follow U.S. EPA, Occupational Safety and Health (OSHA), and corporate health and safety practices.

12.0 REFERENCES

Driscoll, F. G. 1986. "Development of Water Wells." In: *Groundwater and Wells*. Second Edition. Chapter 15. Johnson Filtration Division, St. Paul, Minnesota. p. 497-533.

Freeze, Allan R. and John A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Keel, J.F. and Kwasi Boating. 1987. "Monitoring Well Installation, Purging, and Sampling Techniques - Part 1: Conceptualizations". *Groundwater*, 25(3):300-313.

Keel, J.F. and Kwasi Boating. 1987. "Monitoring Well Installation, Purging, and Sampling Techniques - Part 2: Case Histories". *Groundwater*, 25(4):427-439.

13.0 APPENDICES

This section is not applicable to this SOP.



MONITOR WELL INSTALLATION

SOP#: 2048
DATE: 03/18/96
REV. #: 0.0

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to provide an overview of the methods used for groundwater monitor wells. Monitor well installation create permanent access for collection of samples to assess groundwater quality and the hydrogeologic properties of the aquifer in which contaminants may exist. Such wells should not alter the medium which is being monitored.

The most commonly used drilling methods are: the hollow-stem auger, cable tool, and hydraulic rotary. Rotary drilling can utilize mud rotary or air rotary methods.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, depending on site conditions, equipment limitations, or limitations imposed by the procedures themselves. In all instances, the ultimate procedures employed should be documented and described in the final report as well as in logbooks.

Mention of trade names or commercial products does not constitute United States Environmental Protection Agency (U.S. EPA) endorsement or recommendation for use.

2.0 METHOD SUMMARY

There is no ideal monitor well installation method for all conditions therefore, hydrogeologic conditions at the site as well as project objectives must be considered before deciding which drilling method is appropriate.

2.1 Hollow-Stem Augering

Outside diameters of hollow-stem augers generally range from 6 1/4 inches to 22 inches with corresponding inner diameters ranging from 2 1/4 inches to 13 inches. Auger lengths are usually 5 feet

which allows easy handling. However, lengths of 10 or 20 feet may be used for deeper holes drilled with machines capable of handling the extended lengths. Formation samples can be taken in a number of ways, depending on the accuracy required. Cuttings may suffice for shallow depths but become less representative with depth, particularly below the water table. The most accurate samples are obtained with various coring devices, such as split spoons or shelby tubes which can be used inside the augers. Continuous cores can also be taken with a thin-walled tube which is inserted into the lowest auger and locked in place. The tube is retracted with a wire line and hoist after the hole has been advanced the length of the auger. A bottom plug in the cutting head or bit prevents cuttings from entering the augers until the first core sample is taken and the plug is knocked out.

In unconsolidated material, the augers serve as a temporary casing and gravel-packed wells can be constructed inside the augers and then the augers withdrawn. Well development is usually less difficult than with wells drilled by the mud rotary method because a bentonite drilling fluid is not normally used.

2.2 Cable Tool Drilling

Cable tool drilling is a percussion method in which a bit, attached to a drilling string, is lifted and dropped. The drilling string, consists (bottom to top) of the bit, drill stem, drilling jars, socket, and wire cable. A walking beam on the drilling rig provides the lifting and dropping motion to the wire cable and hence to the drilling string. The repeated action breaks or loosens the formation material which mixes with formation water or water added to the hole by the operator to form a slurry. The slurry facilitates removal of the cuttings which are periodically removed from the hole with a bailer. In unconsolidated formations, steel casing must be driven or pushed into the ground as the drilling progresses in order to prevent hole collapse. A hardened steel drive shoe on the bottom end of the

casing prevents damage during driving. A well may then be constructed inside the steel casing and the casing pulled back. In consolidated formations, the casing may be driven through the weathered zone, and seated in solid rock. The hole below the casing may remain open or may be fitted with a smaller diameter inner casing and screen, depending on the sampling requirements. Depending on formation material, extensive well development may often not be necessary.

2.3 Rotary Drilling

2.3.1 Mud Rotary Method

In the mud rotary method the drill bit is rotated rapidly to cut the formation material and advance the borehole. The drill bit is attached to hollow drilling rods which transfer power from the rig to the bit. In conventional rotary drilling, cuttings are removed by pumping drilling fluid (water, or water mixed with bentonite or other additives) down through the drill rods and bit, and up the annulus between the borehole and the drill rods. The drilling fluid flows into a mud pit where the cuttings settle out and then is pumped back down the drill rods. The drilling fluid also cools the bit and prevents the borehole from collapsing in unconsolidated formations.

Sampling may be done from the cuttings but samples are generally mixed and the amount of fine material may not be accurately represented. Coring may be done through the drill rods and bit if a coring bit (with a center opening big enough to allow passage of the coring tube) is used. When drilling unconsolidated formations, a temporary surface or shallow casing may have to be installed in order to prevent cross-contamination, hole collapse, or wall erosion by the drilling fluid. Casing (riser pipe), screen, and gravel pack are usually installed in the open hole or through the surface casing. Once the well is constructed, extensive well development may be necessary in order to remove drilling fluid from the formation.

2.3.2 Air Rotary Method

The air rotary method uses air as the drilling fluid. Air is forced down the drill rods by an air compressor, escapes out of the bit and returns to the surface in the annular space between the hole wall and the drill string. Cuttings are moved out of the hole by the ascending air and collect around the rig. Cuttings are

mixed and may not always be representative of the depth currently being drilled. In the conventional air rotary method, the drill string operates in a manner similar to that described for the mud rotary system. In a "hammer" or "down-the-hole" air rotary method, the bit is pneumatically driven rapidly against the rock in short strokes while the drilling string slowly rotates. The use of air rotary methods are generally limited to consolidated and semi-consolidated formations. Casing is often used in semi-consolidated formations and through the weathered portion of consolidated formations to prevent hole collapse. In environmental work, the air supply must be filtered to prevent introduction of contamination into the borehole.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

Often, a primary objective of the drilling program is to obtain representative lithologic or environmental samples. The most common techniques for retrieving samples are:

In unconsolidated formations:

- C Split spoon sampling, carried out continuously or at discrete intervals during drilling, as summarized in ASTM Method D-1586-84, Split Barrel Sampling
- C Shelby tube sampling when an undisturbed sample is required from clayey or silty soils, especially for geotechnical evaluation or chemical analysis
- C Cutting collection when a general lithologic description and approximate depths are sufficient

In consolidated formations:

- C Rock coring at continuous or discrete intervals
- C Cutting collection when a general lithologic description and approximate depths are sufficient

When collecting environmental samples, the amount of sample to be collected and the proper sample container type (i.e., glass, plastic), chemical preservation, and storage requirements are dependent on the matrix being sampled and the parameter(s) of interest. Sample preservation, containers, handling

and storage for air and waste samples are discussed in the specific SOPs for the technique selected.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

Advantages and disadvantages of the various drilling methods are summarized below.

4.1 Auger Drilling

The advantages of auger drilling are:

- C Relatively fast and inexpensive
- C Because augers act as temporary casing, drilling fluids are not used resulting in reduced well development

The disadvantages of auger drilling are:

- C Very slow or impossible to use in coarse materials such as cobble or boulders
- C Cannot be used in consolidated formations and is generally limited to depths of approximately 100 feet in order to be efficient

4.2 Cable Tool Drilling

The advantages of cable tool drilling are:

- C Relatively inexpensive with minimum labor requirements
- C The water table and water bearing zones are easily identified
- C Driven casing stabilizes borehole and minimizes potential for cross-contamination
- C Especially successful in drilling caving formations or formations containing boulders
- C Accurate formation samples can usually be obtained from cuttings

The disadvantages of cable tool drilling are:

- C Extremely slow rate of drilling

- C Necessity to drive casing may limit depth in large diameter holes.

4.3 Rotary Drilling

4.3.1 Mud Rotary Drilling

The advantages of mud rotary drilling are:

- C Fast, more than 100 feet of borehole advancement per day is common
- C Provides an open borehole, necessary for some types of geophysical logging and other tests

The disadvantages of mud rotary drilling are:

- C Potential for cross-contamination of water-bearing zones
- C Drill cuttings may be mixed and not accurately represent lithologies at a given drilling depth
- C Drilling mud may alter the groundwater chemistry
- C Water levels can only be determined by constructing wells
- C Drilling mud may change local permeability of the formation and may not be entirely removed during well development
- C Disposal of large volumes of drilling fluid and cuttings may be necessary if they are contaminated

4.3.2 Air Rotary Drilling

The advantages of air rotary drilling are:

- C Fast, more than 100 feet of borehole advancement a day is possible
- C Preliminary estimates of well yields and water levels are often possible
- C No drilling fluid to plug the borehole

The disadvantages of air rotary drilling are:

- C Generally cannot be used in unconsolidated formations
- C In contaminated zones, the use of high-pressure air may pose a significant hazard to the drill crew because of transport of contaminated material up the hole
- C Introduction of air to the groundwater could reduce concentration of volatile organic compounds

5.0 EQUIPMENT

The following equipment is necessary for the site geologist:

- C Metal clipboard box case (container for well logs)
- C Ruler
- C Depth sounder
- C Water level indicator
- C All required health and safety gear
- C Sample collection jars
- C Trowels
- C Description aids (Munsell color chart, grain size charts, etc.)
- C Geolis® Logbooks (Appendix A)
- C Field Logbook

Equipment and tools to install the well are normally provided by the drilling contractor.

6.0 REAGENTS

Reagents are not required for preservation of soil samples. Samples should, however, be cooled to 4° C and protected from sunlight in order to minimize any potential reaction due to the light sensitivity of the sample. Decontamination of drilling equipment should follow the Sampling Equipment Decontamination SOP and the site-specific work plan.

7.0 PROCEDURES

7.1 Preparation

All drilling and well installation programs must be planned and supervised by a professional geologist/hydrogeologist.

The planning, selection and implementation of any

monitor well installation program should include the following:

- C Review of existing data on site geology and hydrogeology including publications, air photos, water quality data, and existing maps. These may be obtained from local, state or federal agencies
- C Assessment of the site to determine potential access problems for drill rig, locate water supply sources, establish equipment storage area, and observe outcrops
- C Perform utilities check, note location of underground utilities and of overhead electrical wires
- C Preparation of a Site Safety Plan
- C Select drilling, sampling and well development methods
- C Determination of well construction specifications (i.e., casing and screen materials, casing and screen diameter, screen length and screen interval, filter pack and screen slot size)
- C Determination of the need for containing drill cuttings and fluids and their method of disposal
- C Preparation of work plan including all of the above
- C Preparation of and execute the drilling contract

7.2 Field Preparation

Prior to mobilization, the drill rig and all associated equipment should be thoroughly decontaminated by a steam/pressure washer to remove all oil, grease, mud, etc. Before drilling each boring, all the "down-the-hole" drill equipment should be steam cleaned and rinsed with potable water to minimize cross-contamination. Special attention should be given to the threaded section of the casings, and to the drill rods. All drilling equipment should be steam-cleaned at completion of the project to ensure that no contamination is transported to or from the sampling site.

7.3 Well Construction

The well casing material should not interact with the groundwater. Well casings for environmental projects are usually constructed of polyvinyl chloride (PVC), Teflon™, fiberglass, or stainless steel. Details of the construction methods are given in Sections 7.3.1 and 7.3.2.

7.3.1 Bedrock Wells

Wells completed in bedrock will be drilled using the air or mud rotary method. Crystalline rock wells are usually drilled most efficiently with the air rotary method while consolidated sedimentary formations are drilled using either the air rotary or mud rotary method. The compressed air supply will be filtered prior to introduction into the borehole to remove oil or other contaminants. Bedrock wells may be completed as an open-hole, providing that borehole cave-in is not a possibility.

Bedrock wells will be advanced with air or mud rotary methods until a minimum of 5 feet of competent rock has been drilled. Minimum borehole diameter will be 8 inches. The drill string will then be pulled from the borehole and 6-inch I.D. Schedule 80 or 40 PVC casing inserted. Portland cement/bentonite grout will be pumped into the hole and up the annular space outside the casing. After the grout has set (minimum of 24 hours), the cement will be drilled out and the borehole advanced to the desired depth. Figure 1 (Appendix B) shows typical construction details for an open-hole bedrock well.

The preferred method of well completion for the bedrock wells will be open-hole. However, if the open borehole is subject to cave-in, the well(s) will be completed as screened and cased sand-packed wells. For details of completion see Section 7.3.2.

7.3.2 Overburden Well Construction

Any of the drilling methods discussed in this SOP can be used to drill or set a well in the overburden. The hollow-stem method is the preferred choice for shallow (<100 ft.) overburden wells because the well can be constructed inside of the augers. Details of the construction are provided below and are shown in Figure 2 (Appendix B).

1. The screen slot size will be determined by the site hydrologist, based upon sand-pack size. The length of screen used will be site-dependent. Casing sections will be flush-threaded. Screw-threaded bottom plugs will be used. To prevent introduction of contaminants into the well, no glue-connected fittings will be used. Each piece of PVC pipe, screen, and the bottom plug will be steam-cleaned before lowering into the borehole. The site hydrogeologist is responsible for the supervision of all steam cleaning procedures.
2. The annular space between the well screen and the borehole wall will be filled with a uniform gravel/sand pack to serve as a filter media. For wells deeper than approximately 50 feet, or when recommended by the site geologist, the sand pack will be emplaced using a tremie pipe. A sand slurry composed of sand and potable water will be pumped through the tremie pipe into the annulus throughout the entire screened interval, and over the top of the screen. Allowance must be made for settlement of the sand pack.
3. The depth of the top of the sand will be determined using the tremie pipe, thus verifying the thickness of the sand pack. Additional sand shall be added to bring the top of the sand pack to approximately 2 to 3 feet above the top of the well screen. Under no circumstances should the sand pack extend into any aquifer other than the one to be monitored. In most cases, the well design can be modified to allow for a sufficient sand pack without threat of crossflow between producing zones through the sand pack.
4. In materials that will not maintain an open hole using hollow-stem augers, the temporary or outer casing will be withdrawn gradually during placement of sand pack/grout. For example, after filling two feet with sand pack, the outer casing should be withdrawn 2 feet. This step of placing more gravel and withdrawing the outer casing should be repeated until the level of the sand pack is approximately 3 feet above the top of the well screen. This ensures that there is no locking of the permanent (inner) casing in the outer casing.

5. A bentonite seal of a minimum 2-foot vertical thickness will be placed in the annular space above the sand pack to separate the sand pack from the cement surface seal. The bentonite will be placed through a tremie pipe or poured directly into the annular space, depending upon the depth and site conditions. The bentonite will be pourable pellets. The hydrogeologist will record the start and stop times of the bentonite seal emplacement, the interval of the seal, the amount of bentonite that was used, and problems that arise. The type of bentonite and the supplier will also be recorded.

A cap placed over the top of the well casing before pouring the bentonite pellets will prevent pellets from entering the well casing.
6. If a slurry of bentonite is used as annular seal, it is prepared by mixing powdered or granular bentonite with potable water. The slurry must be of sufficiently high specific gravity and viscosity to prevent its displacement by the grout to be emplaced above it. As a precaution (regardless of depth) and depending on fluid viscosity, a few handfuls of bentonite pellets may be added to solidify the bentonite slurry surface.
7. Cement and/or bentonite grout is placed from the top of the bentonite seal to the ground surface.

Only Type I or II cement without accelerator additives may be used. An approved source of potable water must be used for mixing grouting materials. The following mixes are acceptable:
 - C Neat cement, a maximum of 6 gallons of water per 94 pound bag of cement
 - C Granular bentonite, 1.5 pounds of bentonite per 1 gallon of water
 - C Cement-bentonite, 5 pounds of pure bentonite per 94 pound bag of cement with 7-8 gallons of water
 - C Cement-bentonite, 6 to 8 pounds of pure bentonite per 94 pound bag of cement with 8-10 gallons of water, if water mixed
- C Non-expandable cement, mixed at 7.5 gallons of water to one half (1/2) teaspoon of Aluminum Hydroxide, 94 pounds of neat cement (Type I) and 4 pounds of bentonite
- C Non-expandable cement, mixed at 7 gallons of water to one half (1/2) teaspoon of Aluminum Hydroxide, 94 pounds of neat cement (Type I and Type II)
8. Grout is pumped through a tremie pipe (normally a 1.25-inch PVC or steel pipe) to the bottom of the annulus until undiluted grout flows from the annulus at the ground surface
9. In materials that will not maintain an open hole, the temporary steel casing should be withdrawn in a manner that prevents the level of grout from dropping below the bottom of the casing.
10. Additional grout may be added to compensate for the removal of the temporary casing and the tremie pipe to ensure that the top of the grout is at or above ground surface. After the grout has set (about 24 hours), any depression due to settlement is filled with a grout mix similar to that described above.
11. The protective casing should now be set. Casing may be a 5 foot minimum length of black iron or galvanized pipe extending about 1.5 to 3 feet above the ground surface, and set in concrete or cement grout. The protective casing diameter should be 4 inches greater than the well casing. A 0.5-inch drain hole may be installed near ground level. A flush-mount protective casing may also be used in areas of high traffic or where access to other areas would be limited by a well stick-up.
12. A protective steel cap, secured to the protective casing by a padlock, should be installed.
13. Steel guard posts should be installed around the protective casing in areas where vehicle traffic may be a problem. Posts should have a minimum diameter of 3 inches and be a

minimum of 4 feet high.

14. All monitor wells should be labelled and dated with paint or steel tags.

7.4 Well Development

Well development is the process by which the aquifer's hydraulic conductivity is restored by removing drilling fluids, and fine-grained formation material from newly installed wells. Two methods of well development that are commonly used are surging and bailing, and overpumping. A well is considered developed when the pH and conductivity of the groundwater stabilizes and the measured turbidity is <50 nephelometric turbidity units (NTUs).

Surging and bailing will be performed as follows:

1. Measure the total depth (TD) of the well and depth to water (DTW).
2. Using an appropriately sized surge block, surge 5-foot sections of well screen, using 10-20 up/down cycles per section. Periodically remove the surge block and bail accumulated sediment from the well, as required.
3. For open-hole wells, a 6-inch surge block will be used inside the cased portion of the well. Sediments will be bailed periodically, as required. Overpumping may be used in combination with surging and bailing for development of bedrock wells. The method(s) used will be based on field conditions encountered, and will be determined by the site hydrogeologist. However, sediment will initially be removed from the wells by bailing in order to minimize the volume of development water generated.

The pump used must be rated to achieve the desired yield at a given depth. The pump system should include the following:

- C A check valve to prevent water from running back into the well when the pump is shut off
- C Flexible discharge hose
- C Safety cable or rope to remove the pump from the well

- C Flow meter monitoring system (measuring bucket or inline flow meter)
- C Generator
- C Amp meter, to measure electrical current (load)

The amp meter is used to monitor pump performance. If the pump becomes clogged, the current will increase due to stress on the pump. If the water level drops below the intake ports, the current will drop due to decreased resistance on the pump.

8.0 CALCULATIONS

To maintain an open borehole during rotary drilling, the drilling fluid must exert a pressure greater than the formation pore pressure. Typical pore pressures for unconfined and confined aquifers are 0.433 define (psi/ft) and 0.465 psi/ft, respectively.

The relationship for determining the hydrostatic pressure of the drilling fluid is:

$$\text{Hydrostatic Pressure (psi)} = \text{Fluid Density (lb/gal)} \times \text{Height of Fluid Column (ft)} \times 0.052$$

The minimum grout volume necessary to grout a well can be calculated using:

$$\text{Grout Vol (ft}^3\text{)} = \text{Vol of Borehole (ft}^3\text{)} - \text{Vol of Casing (ft}^3\text{)} = L (r_b^2 - r_c^2)$$

where:

- L = length of borehole to be grouted (ft)
- r_b = radius of boring (ft)
- r_c = radius of casing (ft)

9.0 QUALITY ASSURANCE/ QUALITY CONTROL

There are no specific quality assurance activities that apply to the implementation of these procedures. However, the following general QA procedures apply:

1. All data must be documented on standard well completion forms, field data sheets or within field/site logbooks. Descriptive logs, pump tests, and well completion data are entered on Geolis® forms. The Geolis® forms are used to ensure data is collected uniformly by all Site Geologists and provide

input to a standardized computer well file. Appendix A contains examples of Geolis® forms used to record descriptions of geologic samples.

2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation and must be documented.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

Drilling rigs and equipment present a variety of safety hazards. REAC personnel working around drilling rigs should know the position of the emergency "kill" switch. Wirelines and ropes should be inspected and frayed or damaged sections discarded. Swivels and blocks should turn freely. Gages should be operational and controls clearly marked. All underground utilities should be clearly marked, and drillers should be aware of any overhead hazards such as power lines. Avoid drilling in these areas. Ear protection should be worn when working around drilling equipment for extended periods of time, particularly air rotary equipment. Failure to follow safety procedure or wear the proper personal protection gear on the part of either the drilling crew or REAC personnel may result in dismissal from the job.

When working with potentially hazardous materials, follow U.S. EPA, OSHA, and corporate health and safety practices.

12.0 REFERENCES

American Society for Testing and Materials. 1991. Annual Book of ASTM Standards. Designation: D5092-90 Standard Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers. p. 1081-1092. Philadelphia, PA.

Boateng, K., P.C. Evens, and S.M. Testa. 1984. "Groundwater Contamination of Two Production Wells: A Case History." *Groundwater Monitoring Review*, V.4, No. 2, p. 24-31.

Keely, J.F. and Kwasi Boateng. 1987. "Monitoring Well Installation, Purging, and Sampling Techniques - Part 1: Conceptualizations." *Groundwater* V. 25, No. 3, p. 300-313.

Keely, J.F. and Kwasi Boateng. 1987. "Monitoring Well Installation, Purging, and Sampling Techniques - Part 2: Case Histories." *Groundwater* V. 25, No. 4, p. 427-439.

Driscoll, F.G. 1986. *Groundwater and Wells* (2nd ed.): Johnson Division, UOP Inc., St. Paul, MN. p. 1089

U.S. EPA. 1987. A Compendium of Superfund Field Operations Methods. EPA/540/p-87/001 Office of Emergency and Remedial Responses. Washington, DC.

APPENDIX A

Geolis Forms

Form 1. Geolis® Borehole Logging Form

GEOLIS® Borehole Logging Form

COMPANY: _____		LOCATION ID: _____		
CLIENT: _____		DATE: _____		
PROJECT: _____		LOGGER: _____		
SITE / AREA: _____		SIGNATURE: _____		

SAMPLING METHOD: 9PB - CBS - STS - CTS - CUT - COR - NS		FLUID ENTRY/ LOSS ZONES: _____ FT/M BGS _____ GPM	
OTHER: _____		ANALYTICAL SAMPLE ID _____	
SAMPLING INTERVAL: _____ TO _____ FT/M BGS		INTERVAL (FT/M BGS) _____	
RECOVERY: _____ / _____ FT/M NA		TYPE / LAB: UND - DIS - CMP / MOB - GEO - CHM - _____	
BLOW COUNT: [] [] [] [] / [] IN/CM NA		TYPE / LAB: UND - DIS - CMP / MOB - GEO - CHM - _____	
RQD: _____ % NA			

SAMPLING INTERVAL No.: _____		LITHOLOGY ARCHIVED? YES - NO NO RECOVERY	MATERIAL: NATURAL - FILL - UNCERTAIN		
LITHOLOGIC INTERVAL No.: _____			OBSERVED: STN - SHN - ODR - PRD - NA - OTHER: _____		
LITHOLOGIC INTERVAL: _____ TO _____ FT/M BGS			INSTRUMENT 1 TYPE: _____ READING: _____		
				INSTRUMENT 2 TYPE: _____ READING: _____	

OVERBURDEN SECONDARY TYPE: NA - BED - CLS - MIX COLOR: MUN - GSA COLORATION: UNI - STN - MOT - VAR BOULDERS: _____ % MAX DIAM: _____ IN COBBLES: _____ % MAX DIAM: _____ IN TEXTURE: C - M - F GRAVEL: _____ % SAND: _____ % SILT: _____ % CLAY: _____ % ORGANIC: _____ % ROUNDNESS: GRAVEL: FAC - STR - ANG - SUB - RND - NA SAND: ANG - SUB - RND - NA SORTING: WEL - MOD - POR - NA PLASTICITY: NON - LOW - MOD - HIGH - NA MOISTURE: DRY - MST - WET - SAT - NA CEMENTATION: NON - BLT - MOD - WEL - NA GRAIN TYPE: QTZ - FRG - FOS - BIO - NA MATRIX: MSM - CBM - CAL - OXD - ARG - SIL - NA STRENGTH: VSF - BFT - FRM - STF - VST - HRD NONCOHESIVE: VND - DEN - FIR - LSE - NA UPPER CONTACT: SHP - GRD - DIF - SMC - NA BEDDING THICK: _____ IN/CM No.: _____ TYPE: XBD - RPL - HOR - INC - NA MAS - LNS - LAM - GRU - GRD STRAT UNIT: [] [] [] [] [] [] [] [] [] [] NOTE LINE: [] [] [] [] [] [] [] [] [] []	GRAPHIC LOG	BEDROCK SECONDARY TYPE: NA - BED - VEN - MIX COLOR: MUN - GSA ROCK TYPE: OTHER: _____ SED: SHL - BLT - SST - CGL - LST - DOL - COL MET: SLA - PHY - SHS - GNS - HRN - QZT - MBL IGN: GRN - RHY - BSL - GSR - TUF - BRC TEXTURE: C - M - F NA GRAVEL: _____ % SAND: _____ % SILT: _____ % CLAY/LIME MUD: _____ % GRAIN TYPE: QTZ - FRG - FOS - BIO - NA MATRIX: CAL - MIC - OXD - ARG - SIL - ORG - NA STRENGTH: EWK - VWK - WEK - MOD STR - VST - EST UPPER CONTACT: SHP - GRD - DIF - SAM - NA SECONDARY: VUG - FRC - BED - NA - OTHER POROSITY: HIGH - MOD - LOW WEATHERING: FRB - BLT - MOD - HIGH - CPL - NA
--	-------------	--

NATURAL FRACTURE SETS				
INTERVAL (FT/M BGS)	#/FT-M	DIP	DIR	FILL/SHAPE/ROUGH/SURFACE
---				FILL: GPM - PRT - PUL SHAPE: PLN - CLR - LND - STP - BR ROUGH: SMH - MOD - RSH SURFACE: CLN - MSH - CSD - STN - WTH
---				FILL: GPM - PRT - PUL SHAPE: PLN - CLR - LND - STP - BR ROUGH: SMH - MOD - RSH SURFACE: CLN - MSH - CSD - STN - WTH
---				FILL: GPM - PRT - PUL SHAPE: PLN - CLR - LND - STP - BR ROUGH: SMH - MOD - RSH SURFACE: CLN - MSH - CSD - STN - WTH
---				FILL: GPM - PRT - PUL SHAPE: PLN - CLR - LND - STP - BR ROUGH: SMH - MOD - RSH SURFACE: CLN - MSH - CSD - STN - WTH

NEXT SAMPLING No. _____ DEPTH INTERVAL _____ NOT SAMPLED INTERVAL: _____ / _____ TO _____ NO RECOVERY
--

COMMENTS: (1) _____

 (2) _____


APPENDIX A (Cont'd)

Geolis Forms

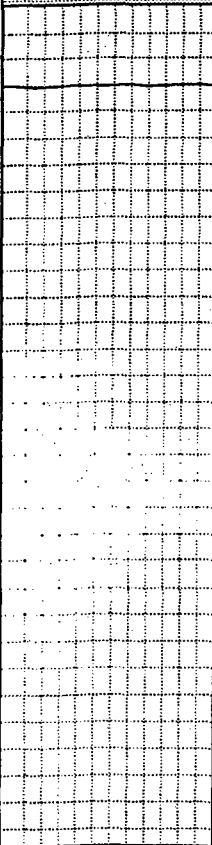
Form 2. Geolis® Well Construction Form

GEOLIS Well Construction Form

Sheet _____ of _____

COMPANY: _____		LOCATION ID: _____		
PROJECT: _____		DATE: _____		
PROPERTY: _____		LOGGER: _____		
SITE/AREA: _____ / _____		SIGNATURE: _____		

START DATE: _____	SURVEYED ELEVATIONS (MSL)	DEPTH TO WATER	DATE / TIME
COMPLETION DATE: _____	GROUND LEVEL: _____ FT/M	_____ FT/M(TOC)	_____
WELL STATUS: PMP - ABN - COL - NOR	MEASURING POINT: _____ FT/M	_____ FT/M(TOC)	_____
STATUS DATE: _____	(TOP OF CASING)	_____ FT/M(TOC)	_____

WELL DIAGRAM - NOT TO SCALE 	DEPTH (FT. BGS)	WELL CODE	WELL TYPE: SCREEN - MULTIPLE SCREEN - OPEN HOLE - NESTED - PROBE CASING: SINGLE - DOUBLE - TRIPLE COMPLETION: FLUSH - PROT - VAULT - CAP - NA TOTAL NO. OF SCREENS/WELLS: _____ SCREEN/WELL NO.: _____ WELL USE: DOM - PUB - IRR - RR - MON - HYD - EXT - DEW - RCH - VSW - INJ - OTH: _____ WELL DESIGN CONSTRUCTION CASING #1: DIAMETER: _____ IN/CM INTERVAL: _____ TO _____ FT/M BGS TYPE: PVC - STN - LCS - GAL - _____ SCHEDULE: 5 - 10 - 20 - 40 - 80 - _____ CASING JOINTS: FLT - BUT - EUT - SOL - WLD - SCW - CAM - OTH: _____ CASING #2: DIAMETER: _____ IN/CM INTERVAL: _____ TO _____ FT/M BGS TYPE: PVC - STN - LCS - GAL - _____ SCHEDULE: 5 - 10 - 20 - 40 - 80 - _____ CASING #3: DIAMETER: _____ IN/CM INTERVAL: _____ TO _____ FT/M BGS TYPE: PVC - STN - LCS - GAL - _____ SCHEDULE: 5 - 10 - 20 - 40 - 80 - _____ STICK UP: INNER CASING: _____ FT/M OUTER CASING: _____ FT/M GROUT: TYPE: CMT - C/S - BEN - HSS - OTH: _____ INTERVAL: _____ TO _____ FT/M BGS PLACEMENT: TRM - PRS - GRV CENTRALIZERS: NON - 1 - 2 - 3 - OTH: _____ SEAL: TYPE 1: _____ INTERVAL: _____ TO _____ FT/M BGS TYPE 2: _____ INTERVAL: _____ TO _____ FT/M BGS SAND PACK: TYPE: _____ INTERVAL: _____ TO _____ FT/M BGS SCREEN OR DEVICE: DIAMETER: _____ IN/CM INTERVAL: _____ TO _____ FT/M BGS TYPE: PVC - STN - LCS - TEF - CER - HDP - OTH: _____ SLOTS: CON - SLH - SLV - BRG - CUT - OTH: _____ SLOT SIZE: 5 - 10 - 20 - 30 - 40 - _____ SLOT STRAT UNIT MONITORED: _____ ESTIMATED WELL YIELD: _____ GPM/LPM DRAWDOWN: _____ FT/M BMP WATER SAMPLING SYSTEM: NON - PMP - PKR - M/S TYPE: _____ SEAL INTERVAL: _____ TO _____ FT/M BGS INTAKE DEPTH: _____ FT/M BGS NOTES: _____ OPEN HOLE: DIAMETER 1: _____ IN/CM INTERVAL: _____ TO _____ FT/M BGS DIAMETER 2: _____ IN/CM INTERVAL: _____ TO _____ FT/M BGS SILT TRAP/BUMP: YES - NO INTERVAL: _____ TO _____ FT/M BGS INSIDE WELL T.D.: _____ FT/M BGS COLLAPSE/BACKFILL: COL - BFL - BTH - NON COLLAPSE INTERVAL: _____ TO _____ FT/M BGS BACKFILL INTERVAL: _____ TO _____ FT/M BGS TYPE: _____
	0	GRS	

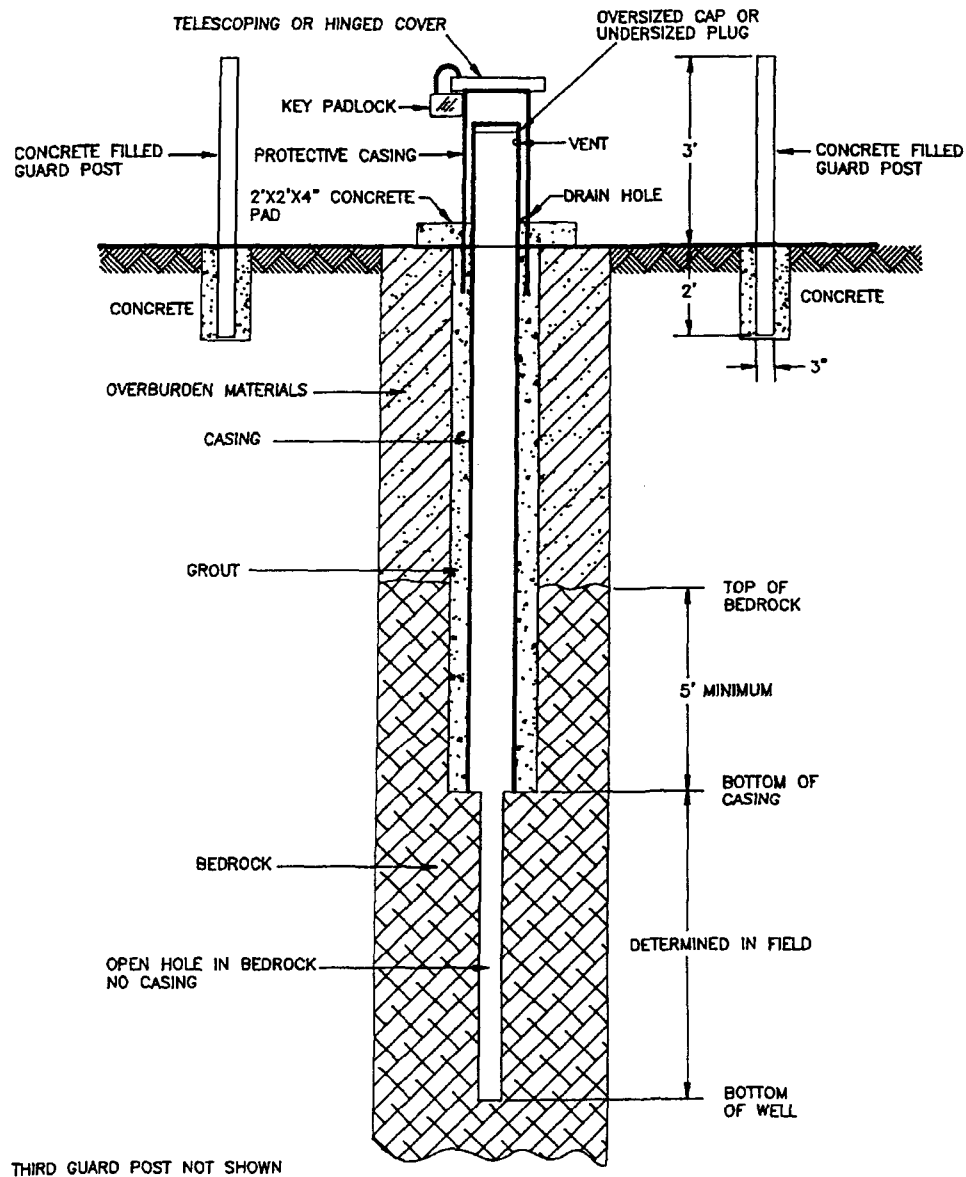
WELL CONSTRUCTION CODES	
GRS = GROUND SURFACE BPS = BOTTOM OF PROTECTIVE CASING TSB = TOP OF SIBTOWITE SEAL TSN = TOP OF SIBTOWITE SDO = BOTTOM OF OUTER CASING TSP = TOP OF SAND PACK	TBC = TOP OF SCREEN TBT = TOP OF SILT TRAP WTD = TOTAL DEPTH WIDE INCL STD = BOREHOLE TOTAL DEPTH TDC = TOP OF CASING (BGS) BBS = BELOW GROUND SURFACE

COMMENTS: _____	
-----------------	--

APPENDIX B

Figures

FIGURE 1. Typical Bedrock Well Construction



Figures

TELESCOPING OR HINGED COVER

KEY PADLOCK

OVERSIZED CAP OR UNDERSIZED PLUG

CONCRETE FILLED GUARD POST

PROTECTIVE CASING PAD

2'x2'x4" CONCRETE PAD

CONCRETE

VENT

DRAIN HOLE

CONCRETE

3"

2"

3"

CASING

GROUT

BENTONITE SEAL

2' MINIMUM

TOP OF BENTONITE

TOP OF SAND

2' MINIMUM

FILTER PACK

TOP OF SCREEN

SCREEN

DETERMINED IN FIELD

DETERMINED IN FIELD

CAP OR PLUG

BOTTOM OF SCREEN

TOTAL DEPTH



PHOTOIONIZATION DETECTOR (PID) HNU

SOP#: 2114
DATE: 10/06/94
REV. #: 0.0

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to describe the procedure for using a photoionization detector (PID). The PID is a portable, nonspecific, vapor/gas detector employing the principle of photoionization to detect a variety of chemical compounds, both organic and inorganic, in air. This procedure is applicable to the HNU PI-101, HNU ISPI-101, and HW-101 used for air monitoring.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent on site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

Mention of trade names or commercial products does not constitute U.S. Environmental Protection Agency (U.S. EPA) endorsement or recommendation for use.

2.0 METHOD SUMMARY

The PID is a useful general survey instrument at hazardous waste sites. A PID is capable of detecting and measuring real-time concentrations of many organic and inorganic vapors in air. A PID is similar to a flame ionization detector (FID) in application; however, the PID has somewhat broader capabilities in that it can detect certain inorganic vapors. Conversely, the PID is unable to respond to certain low molecular weight hydrocarbons, such as methane and ethane, that are readily detected by FID instruments.

The PID employs the principle of photoionization. The analyzer will respond to most vapors that have an ionization potential less than or equal to that supplied by the ionization source, which is an ultraviolet (UV) lamp. Photoionization occurs when an atom or molecule absorbs a photon of sufficient energy to

release an electron and form a positive ion. This will occur when the ionization potential of the molecule in electron volts (eV) is less than the energy of the photon. The sensor is housed in a probe and consists of a sealed ultraviolet light source that emits photons with an energy level high enough to ionize many trace organics, but not enough to ionize the major components of air (e.g., nitrogen, oxygen, carbon dioxide). The ionization chamber exposed to the light source contains a pair of electrodes, one a bias electrode, and the second the collector electrode. When a positive potential is applied to the bias electrode, an electro-magnetic field is created in the chamber. Ions formed by the adsorption of photons are driven to the collector electrode. The current produced is then measured and the corresponding concentration displayed on a meter, directly, in units above background. Several probes are available for the PID, each having a different eV lamp and a different ionization potential. The selection of the appropriate probe is essential in obtaining useful field results. Though it can be calibrated to a particular compound, the instrument cannot distinguish between detectable compounds in a mixture of gases and, therefore, indicates an integrated response to the mixture.

Three probes, each containing a different UV light source, are available for use with the HNU. Energies are 9.5, 10.2, and 11.7 eV. All three detect many aromatic and large molecular hydrocarbons. The 10.2 eV and 11.7 eV probes, in addition, detect some smaller organic molecules and some halogenated hydrocarbons. The 10.2 eV probe is the most useful for environmental response work, as it is more durable than the 11.7 eV probe and detects more compounds than the 9.5 eV probe.

Gases with ionization potentials near to or less than that of the lamp will be ionized. These gases will thus be detected and measured by the analyzer. Gases with ionization potentials higher than that of the lamp will not be detected. Ionization potentials for various atoms, molecules, and compounds are given in

Table 1 (Appendix A). The ionization potential of the major components of air, oxygen, nitrogen, and carbon dioxide, range from about 12.0 eV to about 15.6 eV and are not ionized by any of the three lamps.

Table 2 (Appendix A) illustrates ionization sensitivities for a large number of individual species when exposed to photons from a 10.2 eV lamp. Applications of each probe are included in Table 3 (Appendix A).

While the primary use of the HNU is as a quantitative instrument, it can also be used to detect certain contaminants, or at least to narrow the range of possibilities. Noting instrument response to a contaminant source with different probes can eliminate some contaminants from consideration. For instance, a compound's ionization potential may be such that the 9.5 eV probe produces no response, but the 10.2 eV and 11.7 eV probes do elicit a response.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

This section is not applicable to this SOP.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

4.1 PID Instrument Limitations

1. The PID is a nonspecific total vapor detector. It cannot be used to identify unknown substances; it can only roughly quantify them.
2. The PID must be calibrated to a specific compound.
3. The PID does not respond to certain low molecular weight hydrocarbons, such as methane and ethane. In addition, the HNU does not detect a compound if the probe has a lower energy than the compound's ionization potential.
4. Certain toxic gases and vapors, such as carbon tetrachloride and hydrogen cyanide, have high ionization potentials and cannot be detected with a PID.

5. Certain models of PID instruments are not intrinsically safe. The HNU PI-101 and HW-101 are not designed for use in potentially flammable or combustible atmospheres. Therefore, these models should be used in conjunction with a Combustible Gas Indicator. The ISPI-101 is intrinsically safe, however.
6. Electrical power lines or power transformers may cause interference with the instrument and thus cause measurement errors. Static voltage sources such as power lines, radio transmissions, or transformers may also interfere with measurements.
7. High winds and high humidity will affect measurement readings. The HNU may become unusable under foggy or humid conditions. An indication of this is the needle dropping below zero, or a slow constant climb on the read-out dial.
8. The lamp window must be periodically cleaned to ensure ionization of the new compounds by the probe (i.e., new air contaminants).
9. The HNU measures concentrations from about 1-2000 ppm, although the response is not linear over this entire range. For example, if calibrated to benzene, the response is linear from about 0-600 units above background. This means the HNU reads a true concentration of benzene only between 0 and 600. Greater concentrations are detected at a lower level than the true value.
10. This instrument is not to be exposed to precipitation (rain). The units are not designed for this service.
11. Do not use this instrument for head space analysis where liquids can inadvertently be drawn into the probe.

4.2 Regulatory Limitations

Transport of calibration gas cylinders by passenger and cargo aircraft must comply with International Air Transport Association (IATA) Dangerous Goods

Regulations or the U.S. Code of Federal Regulations, 49 CFR Parts 100-177. A typical calibration gas included with a PID is isobutylene. It is classified as a non-flammable gas, UN #1556 and the proper shipping name is Compressed Gas. It must be shipped by cargo aircraft only.

5.0 EQUIPMENT/APPARATUS

The following equipment is required for PID operation:

- C PID (HNU)
- C Operating manual
- C Probes: 9.5 eV, 10.2 eV, or 11.7 eV
- C Battery charger for PID
- C Spare batteries
- C Jeweler's screwdriver for adjustments
- C Tygon tubing
- C NBS traceable calibration gas
- C "T" valve for calibration
- C Field Data Sheets/Site Logbook
- C Intake assembly extension
- C Strap for carrying PID
- C Teflon tubing for downhole measurements
- C Plastic bags for protecting the PID from moisture and dirt

Note: Battery charge status - This instrument may be kept on continuous charge without battery damage.

6.0 REAGENTS

- C Isobutylene standards for calibration
- C Benzene reference standard
- C Methanol for cleaning ionization chamber (GC grade)
- C Mild soap solution for cleaning unit surfaces
- C Specific gas standards when calibrating to a specific compound
- C Light source cleaning compound Cat. No. PA101534-A1 (For use only with 9.5 and 10.2 lamps)

The HNU is calibrated in accordance with the operations manual using isobutylene as the calibration standard. The operations manual may also be referred to for alternate calibration to a specific compound.

7.0 PROCEDURES

7.1 Preparation

Check out and ensure the proper operation of the PID, as appropriate, using the equipment checklist provided in Sections 5.0 and 6.0 and the steps listed below.

7.2 Start-Up Procedures

1. Allow the temperature of the unit to equilibrate to its surrounding. This should take about five minutes.
2. Attach the probe to the read-out unit. Match the alignment key, then twist the connector clockwise until a distinct locking is felt. Make sure the microswitch (red button) is depressed by the locking ring.
3. Turn the FUNCTION switch to the battery check position. Check to ensure that the indicator reads within or beyond the green battery arc on the scale plate. If the indicator is below the green arc, or if the red LED comes on, the battery must be charged prior to using.
4. To zero the instrument, turn the FUNCTION switch to the STANDBY position and rotate the ZERO POTENTIOMETER until the meter reads zero. Wait 15-20 seconds to ensure that the zero adjustment is stable; if not, then readjust.
5. Check to see that the SPAN POTENTIOMETER is set at the appropriate setting for the probe being used (i.e., 9.8 for the 10.2 eV probe, 5.0 for the 11.7 eV probe, 1 for the 9.5 eV probe. Note: The setting may vary based on the intensity of the light source).
6. Set the FUNCTION switch to the desired range (i.e., 0-20, 0-200, 0-2000).
7. Listen for the fan operation to verify fan function.

8. Look for ultraviolet light source in the probe to verify function. Do not look at light source from closer than six inches with unprotected eyes, observe only briefly.
9. Check instrument with an organic point source, such as a magic marker, prior to survey to verify instrument function.
10. Routinely during the day, verify the useful battery life by turning the function switch to BATT and schedule the instrument's use accordingly.

7.3 Field Operation

7.3.1 Field Calibration

1. Follow the start-up procedure in Section 7.2.
2. Set the FUNCTION switch to the range setting which includes the concentration of the calibration gas.
3. Attach a regulator to a disposable cylinder of calibration gas. Connect the regulator to the probe of the HNU with a piece of clean tygon tubing. Open the valve on the regulator.
4. After 15 seconds, the meter reading should equal the response value as indicated on the calibration gas cylinder used. If the reading is within $\pm 15\%$ of the response value, then the instrument can be field calibrated to the response value using the external SPAN ADJUSTMENT control. The SPAN ADJUSTMENT control should be adjusted to a lower setting until the correct reading has been obtained. The lower the number on the SPAN ADJUSTMENT control, the greater the instrument sensitivity. If the SPAN ADJUSTMENT control has to be adjusted below a setting of 4.00, the unit should be red-tagged and returned for repairs.
5. If the meter reading is greater than $\pm 15\%$ of the response value of the calibration gas used, then the instrument should be red-tagged and returned for re-calibration.

6. Record the following information in the site logbook: the instrument ID number (U.S. EPA decal or serial number if the instrument is a rental), the initial and final span settings, the date and time, concentration and type of calibration gas used, and the name of the person who field calibrated the instrument.
7. If the PID does not start up, check out, or calibrate properly, the instrument should not be used. Under no circumstances is work requiring air monitoring with a PID to be done without a proper functioning instrument.
8. In some field applications, with the exception of the probe's inlet and exhaust, the PID should be wrapped in clear plastic to prevent it from becoming contaminated and to prevent water from getting inside in the event of precipitation.

7.3.2 Operation

1. All readings are to be recorded in the site logbook. Readings should be recorded, following background readings, as "units above background," not ppm.
2. As with any field instrument, accurate results depend on the operator being completely familiar with the operator's manual. The instructions in the operating manual should be followed explicitly in order to obtain accurate results.
3. Position the probe assembly close to the area to be monitored because the low sampling rate allows for only very localized readings. Under no circumstances should the probe tip assembly be immersed in fluid.
4. While taking care to prevent the PID from being exposed to excessive moisture, dirt, or contamination, monitor the work activity as specified in the site Health and Safety Plan. The PID survey should be conducted at a slow to moderate rate of speed and the intake assembly (the probe) slowly swept from side to side. There is a three to five second delay in read-out depending upon the instruments sensitivity to the contaminant.

5. During drilling activities, PID monitoring is performed at regular intervals downhole, at the headspace, and in the breathing zone. In addition, where elevated organic vapor levels are encountered, monitoring may be performed in the breathing zone during actual drilling. When the activity being monitored is other than drilling, readings should emphasize breathing zone conditions.
6. When the activity is completed or at the end of the day, carefully clean the outside of the PID with a damp disposable towel to remove any visible dirt.

7.4 Post Operation

1. Turn FUNCTION Switch to OFF.
2. Return the PID to a secure area and check the calibration (Section 7.3.1.) before charging. Connect the instrument to charger and plug in the charger. The probe must be connected to the readout unit to charge the HNU.
3. Complete logbook entries, verifying the accuracy of entries and signing/initialing all pages. Following completion of a series of "0" readings, verify the instrument is working as in Section 7.3.1.
4. Check the equipment, repair or replace damaged equipment, and charge the batteries.

7.5 Equipment Calibration

1. Follow the start-up procedure in Section 7.2.
2. Set the FUNCTION switch to the range setting which includes the concentration of the calibration gas.
3. Attach a regulator to a cylinder of calibration gas. Connect the regulator to the probe of the NHU with a piece of clean tygon tubing. Open the valve on the regulator.
4. After 15 seconds, the meter reading should equal the response value as indicated on the calibration gas cylinder used. If the reading is greater than $\pm 15\%$ of the actual

concentration, an internal calibration is necessary. Unlock the SPAN POTENTIOMETER dial before adjusting it. Adjust the SPAN POTENTIOMETER to the span setting recommended for the probe being used (i.e., 9.8 for the 10.2 eV probe, 5.0 for the 11.7 eV probe, 1 for the 9.5 eV probe). To calibrate the instrument, unscrew the bottom support screw and lift the instrument out of the case. Locate and adjust the trimpot "R-32" (near the top of the printed circuit board) by inserting a small screwdriver and gently turning. When the instrument gives the correct reading for the calibration gas being used, reassemble it.

5. Record the following information in the calibration logbook: the instrument identification number (U.S. EPA barcode number or serial number if the instrument is a rental), the initial and final span settings, the date and time, concentration and type of calibration gas used, and the name of the person who calibrated the instrument. Affix a sticker to the instrument indicating the person who performed the calibration, the date of calibration, and the due date of the next calibration.
6. Turn the FUNCTION switch to OFF and connect the instrument to the charger. The probe must be connected to the readout unit to ensure that the unit accepts a charge.

8.0 CALCULATIONS

The HNU is a direct reading instrument. Readings are interpreted as units above background rather than ppm.

9.0 QUALITY ASSURANCE/ QUALITY CONTROL

There are no specific quality assurance activities which apply to the implementation of these procedures. However, the following general QA procedures apply:

1. All data must be documented on field data sheets or within site logbooks.
2. All instrumentation must be operated in

accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation, and they must be documented.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OSHA, or corporate health and safety practices.

The HNU is certified by OSHA standards for use in Class 1, Division 2, Groups A, B, C, and D locations.

12.0 REFERENCES

HNU Systems, Inc. 1975. "Instruction Manual for Model PI-101 Photoionization Analyzer."

U.S. Code of Federal Regulations, 49 CFR Parts 100 to 177, Transportation, revised November 1, 1985.

U.S. Environmental Protection Agency. 1984. "Characterization of Hazardous Waste Sites - A Methods Manual: Volume II, Available Sampling Methods, Second Edition", EPA-600/4-84-076, Environmental Monitoring Systems Laboratory, Office of Research and Development, Las Vegas, Nevada.

International Air Transport Association Dangerous Goods Regulations

APPENDIX A

Tables

TABLE 1. Ionization Potentials

<u>SOME ATOMS AND SIMPLE MOLECULES</u>				<u>PARAFFINS AND CYCLOPARAFFINS</u>	
Molecule	IP(Ev)	Molecule	IP (eV)	Molecule	IP (eV)
H	13.595	I ₂	9.28	Methane	12.98
C	11.264	HF	15.77	Ethane	11.65
N	14.54	HCl	12.74	Propane	11.07
O	13.614	HBr	11.62	n-Butane	10.63
Si	8.149	HI	10.38	I-Butane	10.57
S	10.357	SO ₂	12.34	n-Pentane	10.35
F	17.42	CO ₂	13.79	ii-Pentane	10.32
Cl	13.01	COS	11.18	2,2-Dimethylpropane	10.35
Br	11.84	CS ₂	10.08	n-Hexane	10.18
I	10.48	N ₂ O	12.90	2-Methylpentane	10.12
H ₂	15.426	NO ₂	9.78	3-Methylpentane	10.08
N ₂	15.580	O ₃	12.80	2,2-Dimethylbutane	10.06
O ₂	12.075	H ₂ O	12.59	2,3-Dimethylbutane	10.02
CO	14.01	H ₂ S	10.46	n-Heptane	10.08
CN	15.13	H ₂ Se	9.88	2,2,4-Trimethylpentane	9.86
NO	9.25	H ₂ Te	9.14	Cyclopropane	10.06
CH	11.1	HCN	13.91	Cyclopentane	10.53
OH	13.18	C ₂ N ₂	13.8	Cyclohexane	9.88
F ₂	15.7	NH ₃	10.15	Methylcyclohexane	9.85
Cl ₂	11.48	CH ₃	9.840		
Br ₂	10.55	CH ₄	12.98		

APPENDIX A (Cont'd)

Tables

TABLE 1. Ionization Potentials (Continued)

ALKYL HALIDES

Molecule	IP (eV)	Molecule	IP (eV)
HCl	12.74	1-bromo-2-methylpropane	10.09
Cl ₂	11.48	2-bromo-2-methylpropane	9.89
CH ₄	12.98	1-bromopentane	10.10
Methyl chloride	11.28	HI	10.38
Dichloromethane	11.35	I ₂	9.28
Trichloromethane	11.42	Methyl iodide	9.54
Tetrachloromethane	11.47	Diiodomethane	9.34
Ethyl chloride	10.98	Ethyl iodide	9.33
1,2-Dichloroethane	11.12	1-iodopropane	9.26
1,3-Dichloropropane	10.85	2-iodopropane	9.17
1-chlorobutane	10.67	1-iodobutane	9.21
2-chlorobutane	10.65	2-iodobutane	9.09
1-chloro-2-methylpropane	10.66	1-iodo-2-methylpropane	9.18
2-chloro-2-methylpropane	10.61	2-iodo-2-methylpropane	9.02
HBr	11.62	1-iodopentane	9.19
Br ₂	10.55	F ₂	15.7
Methyl bromide	10.53	HF	15.77
Dibromomethane	10.49	CFCl ₃ (Freon 11)	11.77
Tribromomethane	10.51	CF ₂ Cl ₂ (Freon 12)	12.31
CH ₂ BrCl	10.77	CF ₃ Cl (Freon 13)	12.91
CHBr ₂ Cl	10.59	CHClF ₂ (Freon 22)	12.45
Ethyl bromide	10.29	CF ₂ Br ₂	11.67
1,1-dibromoethane	10.19	CH ₃ CF ₂ Cl (Genetron 101)	11.98
1-bromo-2-chloroethane	10.63	CFCl ₂ CF ₂ Cl	11.99
1-bromopropane	10.18	CF ₃ CCl ₃ (Freon 113)	11.78
2-bromopropane	10.075	CFHBrCH ₂ Br	10.75
1,3-dibromopropane	10.07	CF ₂ BrCH ₂ Br	10.83
1-bromobutane	10.13	CF ₃ CH ₂ I	10.00
2-bromobutane	9.98	n-C ₃ F ₇ I	10.36
1-chloropropane	10.82	n-C ₃ F ₇ CH ₂ Cl	11.84
2-chloropropane	10.78	n-C ₃ F ₇ CH ₂ I	9.96
1,2-dichloropropane	10.87	CF ₂ Br ₂	11.07

APPENDIX A (Cont'd)

Tables

TABLE 1. Ionization Potentials (Continued)

ALIPHATIC ALCOHOL, ETHER, THIOL, AND SULFIDES

Molecule	IP (eV)
Water	12.59
Methyl alcohol	10.85
Ethyl alcohol	10.48
n-propyl alcohol	10.20
i-propyl alcohol	10.16
n-butyl alcohol	10.04
Dimethyl ether	10.00
Diethyl ether	9.53
n-propyl ether	9.27
i-propyl ether	9.20
Hydrogen Sulfide	10.46
Methanethiol	9.440
Ethanethiol	9.285
1-propanethiol	9.195
1-butanethiol	9.14
Dimethyl sulfide	8.685
Ethyl methyl sulfide	8.55
Diethyl sulfide	8.430
di-n-propyl sulfide	8.30

ALIPHATIC ALDEHYDES AND KETONES

Molecule	IP (eV)
Carbon Dioxide	13.79
Formaldehyde	10.87
Acetaldehyde	10.21
Propionaldehyde	9.98
n-butyraldehyde	9.86
Isobutyraldehyde	9.74
n-valeraldehyde	9.82
Isovaleraldehyde	9.71
Acrolein	10.10
Crotonaldehyde	9.73
Benzaldehyde	9.53
Acetone	9.69
Methyl ethyl ketone	9.53
Methyl n-propyl ketone	9.39
Methyl i-propyl ketone	9.32
Diethyl ketone	9.32
Methyl n-butyl ketone	9.34
Methyl i-butyl ketone	9.30
3,3-dimethyl butanone	9.17
2-heptanone	9.33
Cyclopentanone	9.26
Cyclohexanone	9.14
2,3-butanedione	9.23
2,4-pentanedione	8.87

APPENDIX A (Cont'd)

Tables

TABLE 1. Ionization Potentials (Continued)

<u>ALIPHATIC ACIDS AND ESTERS</u>		<u>ALIPHATIC AMINES AND AMIDES</u>	
Molecule	IP (eV)	Molecule	IP (eV)
Carbon Dioxide	13.79	Ammonia	10.15
Formic acid	11.05	Methyl amine	8.97
Acetic acid	10.37	Ethyl amine	8.86
Propionic acid	10.24	n-propyl amine	8.78
n-butyric acid	10.16	i-propyl amine	8.72
Isobutyric acid	10.02	n-butyl amine	8.71
n-valeric acid	10.12	i-butyl amine	8.70
Methyl formate	10.815	s-butyl amine	8.70
Ethyl formate	10.61	t-butyl amine	8.64
n-propyl formate	10.54	Dimethyl amine	8.24
n-butyl formate	10.50	Diethyl amine	8.01
Isobutyl formate	10.46	Di-n-propyl amine	7.84
Methyl acetate	10.27	Di-i-propyl amine	7.73
Ethyl acetate	10.11	Di-n-butyl amine	7.69
n-propyl acetate	10.04	Trimethyl amine	7.82
Isopropyl acetate	9.99	Triethyl amine	7.50
n-butyl acetate	10.01	Tri-n-propyl amine	7.23
Isobutyl acetate	9.97	Formamide	10.25
Sec-butyl acetate	9.91	Acetamide	9.77
Methyl propionate	10.15	N-methyl acetamide	8.90
Ethyl propionate	10.00	N,N-dimethyl formamide	9.12
Methyl n-butyrate	10.07	N,N-dimethyl acetamide	8.81
Methyl isobutyrate	9.98	N,N-diethyl formamide	8.89
		N,N-diethyl acetamide	8.60

APPENDIX A (Cont'd)

Tables

TABLE 1. Ionization Potentials (Continued)

<u>OTHER ALIPHATIC MOLECULES WITH N ATOM</u>		<u>OLEFINS, CYCLO-OLEFINS, ACETYLENES</u>	
Molecule	IP (eV)	Molecule	IP (eV)
Nitromethane	11.08	Ethylene	10.515
Nitroethane	10.88	Propylene	9.73
1-nitropropane	10.81	1-butene	9.58
2-nitropropane	10.71	2-methylpropene	9.23
HCN	13.91	Trans-2-butene	9.13
Acetonitrile	12.22	Cis-2-butene	9.13
Propionitrile	11.84	1-pentene	9.50
n-butyronitrile	11.67	2-methyl-1-butene	9.12
Acrylonitrile	10.91	3-methyl-1-butene	9.51
3-butene-nitrile	10.39	3-methyl-2-butene	8.67
Ethyl nitrate	11.22	1-hexene	9.46
Methyl thiocyanate	10.065	1,3-butadiene	9.07
Ethyl thiocyanate	9.89	Isoprene	8.845
Methyl isothiocyanate	9.25	Cyclopentene	9.01
Ethyl isothiocyanate	9.14	Cyclohexene	8.945
		4-methylcyclohexene	8.91
		4-cinylcyclohexene	8.93
		Cyclo-octatetraene	7.99
		Acetylene	11.41
		Propyne	10.36
		1-butyne	10.18

APPENDIX A (Cont'd)

Tables

TABLE 1. Ionization Potentials (Continued)

<u>SOME DERIVATIVES OF OLEFINS</u>		<u>HETEROCYCLIC MOLECULES</u>	
Molecule	IP (eV)	Molecule	IP (eV)
Vinyl chloride	9.995	Furan	8.89
Cis-dichloroethylene	9.65	2-methyl furan	8.39
Trans-dichloroethylene	9.66	2-furaldehyde	9.21
Trichloroethylene	9.45	Tetrahydrofuran	9.54
Tetrachloroethylene	9.32	Dihdropyran	8.34
Vinyl bromide	9.80	Tetrahydropyran	9.26
1,2-dibromoethylene	9.45	Thiophene	8.860
tribromoethylene	9.27	2-chlorothiophene	8.68
3-chloropropene	10.04	2-bromothiophene	8.63
2,3-dichloropropene	9.82	Pyrrole	8.20
1-bromopropene	9.30	Pyridine	9.32
3-bromopropene	9.7	2-picoline	9.02
CF ₃ CCl=CClCF ₃	10.36	3-picoline	9.04
n-C ₅ F ₁₁ CF=CF ₂	10.48	4-picoline	9.04
Acrolein	10.10	2,3-lutidine	8.85
Crotonaldehyde	9.73	2,4-lutidine	8.85
Mesityl oxide	9.08	2,6-lutidine	8.85
Vinyl methyl ether	8.93	Tribromoethylene	9.27
Allyl alcohol	9.67		
Vinyl acetate	9.19		

APPENDIX A (Cont'd)

Tables

TABLE 1. Ionization Potentials (Continued)

AROMATIC COMPOUNDS

Molecule	IP (eV)	Molecule	IP (eV)
Benzene	9.245	Phenyl isothiocyanate	8.520
Toluene	8.82	Benzonitrile	9.705
Ethyl benzene	3.76	Nitrobenzene	9.92
n-propyl benzene	8.72	Aniline	7.70
i-propyl benzene	8.69	Fluoro-benzene	9.195
n-butyl benzene	8.69	Chloro-benzene	9.07
s-butyl benzene	8.68	Bromo-benzene	8.98
t-butyl benzene	8.68	Iodo-benzene	8.73
o-xylene	8.56	o-dichlorobenzene	9.07
m-xylene	8.56	m-dichlorobenzene	9.12
p-xylene	8.445	p-dichlorobenzene	8.94
Mesitylene	8.40	1-chloro-2-fluorobenzene	9.155
Durene	8.025	1-chloro-3-fluorobenzene	9.21
Styrene	8.47	1-bromo-4-fluorobenzene	8.99
o-methyl styrene	8.35	o-fluorotoluene	8.915
Ethynylbenzene	8.815	m-fluorotoluene	8.915
Napthalene	8.12	p-fluorotoluene	8.785
1-methylnapthalene	7.69	o-chlorotoluene	8.83
2-methylnapthalene	7.955	m-chlorotoluene	8.83
Biphenyl	8.27	p-chlorotoluene	8.70
Phenol	8.50	o-bromotoluene	8.79
Anisole	8.22	m-bromotoluene	8.81
Phenetole	8.13	p-bromotoluene	8.67
Benzaldehyde	9.53	o-iodotoluene	8.62
Acetophenone	9.27	m-iodotoluene	8.61
Benzenethiol	8.33	p-iodotoluene	8.50
Phenyl isocyanate	8.77	Benzotrifluoride	9.68
		o-fluorophenol	8.66

APPENDIX A (Cont'd)

Tables

TABLE 1. Ionization Potentials (Continued)

MISCELLANEOUS MOLECULES

Molecule	IP (eV)
Ethylene oxide	10.565
Propylene oxide	10.22
p-dioxane	9.13
Dimethoxymethane	10.00
Diethoxymethane	9.70
1,1-dimethoxyethane	9.65
Propiolactone	9.70
Methyl disulfide	8.46
Ethyl disulfide	8.27
Diethyl sulfite	9.68
Thiolacetic acid	10.00
Acetyl chloride	11.02
Acetyl bromide	10.55
cyclo-C ₆ H ₁₁ CF ₃	10.46
(n-C ₃ F ₇)(CH ₃)C=O	10.58
Trichlorovinylsilane	10.79
(C ₂ F ₅) ₃ N	11.7
Isoprene	9.08
Phosgene	11.77

APPENDIX A (Cont'd)

Tables

TABLE 2. Relative Photoionization Sensitivities for Gases

Chemical	Relative Sensitivity	Examples
Aromatic	10	Benzene, Toluene, Styrene
Aliphatic Acid	10	Diethylamine
Chlorinated Unsaturated	5-9	Vinyl Chloride, Vinylidene Chloride, Trichloroethylene
Carbonyl	7-9	MEK, MiBK, Acetone, Cyclohexanone
Unsaturated	3-5	Acrolein, Propylene, Cyclohexanone, Allyl Alcohol
Sulfide	3-5	Hydrogen Sulfide, Methyl Mercaptan
Paraffin (C5-C7)	1-3	Pentane, Hexane, Heptane
Ammonia	0.3	
Paraffin (C1-C4)	0	Methane, Ethane

NOTE: Relative sensitivity = meter reading when measuring 10 ppm of the listed gas with instrument with 10.2 eV probe calibrated for 10 ppm of benzene, span pot setting = 9.8 for direct reading of benzene.

APPENDIX A (Cont'd)

Tables

TABLE 3. Typical Applications of Interchangeable Probes

	Ionization Potentials	Relative Sensitivity	
p-Xylene	8.44	0.10	0.104
p-Chlorotoluene	8.70	0.09	0.112
Toluene	8.82	0.09	0.112
o-Chlorotoluene	8.83	0.075	0.112
Ethyl Acetate	9.19	0.075	0.112
Benzene	9.24	0.10	0.10
Methyl Mercaptan	9.24	0.10	0.072
Pyridine	9.32	0.075	0.122
Allyl Alcohol	9.67	0.10	0.111
Crotonaldehyde	9.88	0.075	0.104
Amyl Alcohol	9.80	0.09	0.116
Cyclohexane	9.88	0.075	0.104
Vinyl Chloride	9.95	0.085	0.112
Butanol	10.94	0.09	0.176
Ammonia	10.15	0.06	0.160
Acetic Acid	10.37	0.04	0.560
Ethylene	10.52	0.0	0.320
Ethylene Oxide	10.56	0.0	0.298

$$\text{Relative sensitivity} = \frac{\text{Response with 9.5 or 11.7 eV probe}}{\text{Response with 10.2 eV probe}}$$

GSI Job No. G-2876
April 1, 2004



**GROUNDWATER
SERVICES, INC.**

ATTACHMENT B

PROJECT HEALTH AND SAFETY PLAN

Work Plan for DNAPL Characterization and Remediation Study

Sauget Area 1 Sites
Sauget, Illinois



**GROUNDWATER
SERVICES, INC.**

**GROUNDWATER SERVICES, INC.
HEALTH AND SAFETY PLAN**

2211 Norfolk, Suite 1000
Houston, Texas 77098
713-522-6300

Includes site-specific information for:

Sauget Area 1 Sites
Sauget, Illinois

Work Plan for DNAPL Characterization and
Remediation Study

TABLE OF CONTENTS GSI Health and Safety Plan

1.0	INTRODUCTION	1
1.1	Purpose, Scope, and Applicability	1
1.2	Program Distribution and Revision	2
2.0	ORGANIZATIONAL STRUCTURE.....	2
2.1	GSI Company Safety Administrator	2
2.2	Project Safety Officers.....	2
2.3	Employee Responsibilities.....	3
2.4	Safety Performance Review	3
2.5	Subcontractor Qualification	3
2.6	Coordination of GSI HASP and Site Specific HASPS.....	4
3.0	GENERAL HEALTH AND SAFETY PROCEDURES	4
3.1	General Practices	4
3.2	Heat Stress/Cold Exposure	7
3.3	Drilling, Excavation, and Other Heavy Equipment Operations	9
3.4	Confined Space and Excavation Safety.....	10
3.5	Chemical Hazards.....	10
3.6	Reporting of Safety Concerns and Incident/Accident Investigation.....	11
4.0	HEALTH AND SAFETY TRAINING PROGRAM.....	11
4.1	OSHA "HAZWOPER" Safety Training	11
4.2	Safety Meetings.....	11
4.3	Hazard Communication "HAZCOM" Program	13
4.5	Site-Specific Training.....	13
4.6	Confined Space Entry Training	13
4.7	Other Specialized Training.....	13
5.0	PERSONAL PROTECTIVE EQUIPMENT PROGRAM.....	14
5.1	PPE Selection and Use.....	14
5.2	Inspection, Decontamination, Maintenance, and Storage	15
5.3	Training	15
6.0	RESPIRATORY PROTECTION PROGRAM	16
6.1	Air Monitoring.....	16
6.2	Engineering Controls.....	18
6.3	Respiratory Protective Equipment.....	18

TABLE OF CONTENTS

GSI Health and Safety Plan

7.0	MEDICAL SURVEILLANCE	21
7.1	Applicability.....	21
7.2	Elements of Medical Surveillance	21
7.3	Frequency of Medical Examination	22
7.4	Records of Medical Examination.....	22
7.5	Drugs, Alcohol, and Other Prohibited Items	22
8.0	VEHICLE SAFETY PROGRAM.....	22
9.0	RECORD KEEPING.....	23
10.0	SITE-SPECIFIC SAFETY AND HEALTH PROGRAM	22
10.1	Applicability.....	23
10.2	Site Evaluation and Job Safety Analysis	24
10.3	Elements of the Site-Specific Health and Safety Program.....	24

Appendix A: Company Policy Regarding Drugs, Alcohol, and Other Prohibited Items

Appendix B: Motor vehicle Safety and Defensive Driving Program

Appendix C: Hazard Communication Program

Appendix D: Safety Procedure for Electrical / Hazardous Energy Lockout

Appendix E: Site-Specific Health and Safety Plan, Area 1 Sites, Sauget, Illinois

Appendix F: Attachments to Site-Specific Health and Safety Plan

-Map to St. Mary's Hospital, Sauget, IL

-Map of Solutia W.G. Krummrich Plant, Sauget, IL

**GROUNDWATER SERVICES, INC.
HEALTH AND SAFETY PLAN
(GSI HASP)**

1.0 GSI HEALTH AND SAFETY POLICY

1.1 Purpose, Scope, and Applicability

Purpose. Groundwater Service, Inc. (GSI), is committed to providing a safe and healthy working environment for all of its employees, and to ensuring that our safety performance meets or exceeds our customers' expectations. Accordingly, GSI has developed this written Health and Safety Plan (the GSI HASP) in order to promote safety awareness and safe working practices; establish procedures for safe implementation of field activities; address safety-related concerns; and prevent accidents, injuries and occupational illness.

Scope. The GSI HASP has been designed to comply with applicable standards of the Occupational Safety and Health Administration (OSHA), promulgated in Chapter 29 of the Code of Federal Regulations (29 CFR), which relate to our core business activities in the field of environmental consulting and engineering (SIC 8711). Specifically addressed are requirements Hazardous Waste Operations and Emergency Response ("HAZWOPER," §1910.120); Subpart I, Personal Protective Equipment (PPE, §1910.132–1910.138) including Respiratory Protection (§1910.134); and the Hazard Communication Standard ("HAZCOM," § 1910.1200). Other standards are addressed as applicable. In addition to the main body of this plan, supplemental sections governing Substance Abuse, Driver Safety, Hazard Communication (Hazcom), and Energy Isolation (Lock-out/Tag-out) are included as appendices. Additional sections will be prepared and distributed as needed.

The GSI HASP is designed to accompany, and to be used in conjunction with, site-specific and project-specific HASPs. As allowed by OSHA, the company HASP may be used to specify standard operating procedures, which need not be duplicated in the site-specific plan.

Applicability. The plan applies to all GSI employees working both at GSI facilities (office and warehouse/shop locations), and at all field sites located on the facilities and properties of GSI clients. The principles and safe work practices described in this program also apply to our subcontractors. GSI employees supervising the work of subcontractors are responsible for communicating the requirements of this program to subcontract personnel and for ensuring their conformance with our safety requirements.

Conformance with all elements of the GSI HASP is mandatory. All GSI employees are expected to take primary responsibility for their own safety, to exercise sound judgment, and to make the safe performance of their jobs their first priority. All are required to conduct all work in a safe and careful manner in accordance with the GSI HASP and project- or site-specific safety plans. Failure to abide by the plan may result in disciplinary action, including dismissal, depending on the severity of the violation.

1.2 Program Distribution and Revision

The GSI Health and Safety Plan is distributed to all GSI employees and is readily available to all employees via the computer network server. A copy of the plan is provided to all new employees upon acceptance of employment at GSI. An orientation to the plan is conducted by the GSI Safety Administrator, and each new employee must read, understand, and agree to abide by all aspects of the GSI Health and Safety Program, and must certify in writing their understanding of the program and the requirement to abide by the plan.

The GSI HASP will be updated or augmented as necessary to account for expansion of the services provided, revisions in applicable regulations, and to address the needs of our clients. Plan updates will be distributed to all GSI employees. Upon each revision, the current GSI HASP will be available on the network server and may be downloaded and printed by all employees.

2.0 ORGANIZATIONAL STRUCTURE

2.1 GSI Company Safety Administrator

The GSI Health and Safety Program, including this plan, is administered by the GSI Safety Administrator. Responsibilities include preparation, distribution and updating of the GSI HASP; coordination of safety and health training and medical monitoring; review of site-specific health and safety plans; investigation of on-the-job accidents, injuries and occupational illnesses, and maintenance of health and safety related records and files. In the event of an on-the-job injury, the GSI Safety Administrator is responsible for making a determination of whether the injury is recordable under OSHA, and is responsible for maintaining the OSHA 200 log, and for filing OSHA Form 101, Supplemental Record of Occupational Injury or Illness.

Robert Lee, GSI Vice President, [(713) 522-6300] is the current GSI Safety Administrator. Should a need arise in his absence, Grant Cox, GSI Vice President, may be contacted at the same phone number.

2.2 Project Safety Officers

Site-specific Project Safety Officers (PSO) will be designated for GSI projects involving field activities. On each project, the Project Safety Officer will be designated by the Project Team Leader, and subject to the approval of the Safety Administrator. The PSO must be a qualified person, with knowledge, experience, and training commensurate with the responsibilities for the particular site and project.

The PSO is responsible for communication of project health and safety requirements to project personnel, including subcontractors; conducting project safety meetings; ensuring compliance with the HASP; completing the daily site safety record and related documentation; and for communicating safety-related concerns to the client's on-site safety representative and to the GSI Safety Administrator.

2.3 Employee Responsibilities

All GSI employees are expected to be actively involved in safe work performance. They are expected to take primary responsibility for their own health and safety, and to make the extra effort ensure that of their fellow employees, subcontract personnel, and the people working around them. Compliance with all elements of the GSI HASP and project-specific health and safety plans is mandatory. Beyond that, employees are encouraged to seek additional information whenever appropriate and to provide recommendations for the improvement of our safety performance. In the event that a potentially unsafe condition or action is observed, it is the employees duty to bring that condition to the attention of the appropriate person. It may be necessary at times to remind a co-worker to use the proper procedures or personal protective equipment, to suggest a safer way to perform a task to a project team leader, or to intervene with a co-worker to prevent a potentially unsafe act.

All project-related safety concerns and/or accidents are to be reported immediately to the designated Project Safety Officer. Significant concerns should also be brought to the attention of the GSI Safety Administrator, either directly by the employee, or through the SSO. Reportable safety concerns include, but are not limited to unsafe physical conditions at the a host facility, unsafe work practices, and "near misses" (i.e., incidents in which, while no accident or injury may have occurred, unsafe conditions or actions result in a narrowly averted accident or injury. Non-project safety concerns and/or accidents (e.g., automobile accidents or safety concerns in the GSI office or warehouse) are to be reported directly to the GSI Safety Administrator. Incident investigation policies and procedures are detailed in Section 3.6.

2.4 Safety Performance Review

GSI employees are evaluated on safety awareness and performance during their annual performance reviews. Employees with a demonstrated awareness of safety and a history of safe work performance will be recognized. Poor safety awareness and performance may be grounds for disciplinary action, possibly including termination for serious or repeated violations of safety policies and procedures.

2.5 Subcontractor Qualification

All subcontractors performing site work for GSI must be prequalified, based on safety performance history. Prior to execution of a subcontract agreement, the subcontractor must complete Exhibit A of the standard GSI Subcontract Agreement "Subcontractor's Safety Program and Performance History." Safety performance history must be updated annually.

In order to perform site work for GSI, the Subcontractor must have a documented Health and Safety Program that meets the requirements of the host facility. In general, the following are minimum performance requirements:

- The OSHA/BLS Recordable Injury Frequency and Lost Work Day Injury Rates must be equal to or less than the average rate for the applicable industry, and

- The Workers' Compensation Experience Modification Rate (EMR) must be less than or equal to 1.0.

More stringent requirements may apply, depending on the requirements of the host facility.

2.6 Coordination of GSI HASP with Site-Specific HASPS

As specified in 29 CFR 1910.120, site-specific health and safety plans (SS-HASPs) must be developed for hazardous waste site operations as defined in that standard. These include cleanup operations (including site investigations) at sites involving hazardous wastes or hazardous substances, directed by federal, state, or local government agencies, including sites governed by RCRA, CERCLA, orders issued by state agencies or administered under voluntary cleanup programs.

Site-specific plans must be available on-site at all times work is being performed. As stated in §1910.120, the site-specific plans do not need to repeat all general information and standard procedures provided in the company's HASP. Accordingly, GSI has developed a standard form for developing site-specific HASPS which reference the GSI HASP. When this form is used, it is also required that a copy of the GSI HASP is also located on-site and available to site workers.

3.0 GENERAL HEALTH AND SAFETY PROCEDURES

3.1 General Practices

All GSI employees and subcontractors are expected to work in a manner to protect the environment and the health and safety of themselves and those around them. Specific procedures will be detailed in site-specific health and safety plans prepared for each project. However, the following guidelines apply to all projects at all locations.

3.1.1 Orientation

All new employees will be provided an orientation to the GSI HASP prior to any on-site project work. An orientation will also be given to the site-specific HASP for each project. New employees will spend a minimum of two weeks working under the direct supervision of an experienced GSI employee, and will be overseen in the performance of new tasks for a longer period as needed.

3.1.2 Host Facility Requirements

Health and safety requirements of host facilities at which GSI projects are being conducted will be strictly observed. These may be presented in an orientation conducted at the site or in a contractor safety manual. In some cases, these requirements may differ from GSI standard health and safety standards. In such cases, the more protective standard will apply.

3.1.3 Buddy System

GSI employees will employ the "buddy system" during field operations. Typically, two or more employees will be assigned to field tasks, or a GSI employee may be accompanied by subcontract personnel or client contact. Plant and unit sign-in and sign-out procedures

will be observed, and in some cases, radio contact with a plant control room may be required and may substitute for the physical presence of a "buddy." Some low-risk tasks, such as measurement of water levels or routine inspections in high visibility areas, may be safely performed by an individual working alone. This determination will be made by the Project Team Leader or Site Safety Officer.

3.1.4 House-Keeping

All work areas should be kept neat and free of debris which may pose a trip hazard or otherwise interfere with the safe performance of the work. The work-site should be inspected at the end of each day and prepared for the following day's activities. At the termination of the project, the site should be left free of debris or surplus materials.

3.1.5 Tool Inspection and Use

GSI provides tools for projects, including hand tools, electrically-powered tools, and other powered equipment with moving parts such as cement mixers, gasoline-powered generators and pumps. All tools must be inspected prior to use by the person using them. Tools which are not in proper repair pose a hazard and should not be used.

Electrical tools must be either double-insulated or grounded. Power tools and extension cords which have had the grounding plug removed, or which have damaged insulation exposing the electrical wires must not be used. Electrical tools designed to accommodate guards must have guards in place to protect against accidental contact with moving parts, such as saw-blades, belts, drive chains fly wheels, and pulleys. Eye protection must always be worn when using cutting drilling, chipping, or other tools, which could result in discharge of small particles to the air.

3.1.6 Personal Protective Equipment

On all GSI projects, the minimum required Level D personal protective equipment PPE will include the following: hard hat, safety glasses with side-shields, steel-toed safety shoes or boots, long pants, and shirt with sleeves. Additional PPE required for specific tasks or locations will be specified in site-specific health and safety plans, and may include various types of gloves, hearing protection, chemical-protective clothing, fire-retardant clothing, or respiratory-protective equipment. GSI will provide employees with all necessary PPE. Each employee engaged in field activities will be furnished with a hard hat, safety glasses (prescription if needed), steel toed boots, and air-purifying respirators, for their exclusive use, and will be responsible for maintaining the equipment and arranging for replacement when needed. Disposable equipment will be furnished as needed. The PPE and respiratory protection programs are presented in Sections 5 and 6.

3.1.7 First-Aid

First-aid kits are carried on GSI field vehicles, including rental trucks, and are available in the office and warehouse spaces. The first aid-kit should be inspected prior to project mobilization to ensure it is complete. The kits are equipped for responding to minor injuries such as cuts and scratches. In the event of more serious injuries, aid from properly qualified personnel should be sought, by contacting emergency response providers at a host facility, visiting a hospital emergency room, or by calling 9-1-1.

3.1.8 Fire Protection

GSI employees must observe all host-facility requirements regarding hot-work permits and restrictions on the use of spark-producing equipment such as gasoline-powered engines. Gasoline for use in pumps or other powered equipment must be transported in designated, labeled cans with self-venting, spring-activated lids and flame arresters. Fire-extinguishers are carried on all GSI field vehicles, including rental trucks, and should be placed in an accessible area close to spark-producing equipment.

At the GSI warehouse, flammable and combustible materials must be stored in the appropriate cabinet, which must be closed at all times when not in use. Fire extinguishers are available in the GSI office and warehouse facilities in clearly marked locations.

Smoking is not permitted in any GSI facility, including the office or warehouse, or in GSI vehicles, including rental vehicles, or on job sites, except in designated smoking areas. All host-facility restrictions on possession of smoking materials, matches or lighters must be observed.

3.1.9 Emergency Response

Emergency response procedures, including emergency reporting, will typically be specified by host facilities, and must be followed, including site-specific procedures for notifying emergency response personnel when an emergency is detected. In general, GSI employees are not trained as first responders to emergencies and, unless they have received specific training, should not attempt to perform emergency shut-down, spill abatement, or fire-fighting in cases involving a significant risk of injury or chemical exposure.

Unless otherwise directed by the host facility, in the event of a fire or chemical release to the air, all powered equipment, including vehicles, should be shut down and the keys left in the vehicle. The project team leader or site safety officer should account for all project personnel on-site. The wind direction relative to the release should be noted and personnel should move upwind or cross-wind to a designated assembly area. In the event of fire, unless they have received specific training, employees should not attempt to extinguish the blaze if it places the individual at risk.

In the GSI offices, the emergency procedures specified by the building management will be observed. Unless otherwise directed, the building should be exited by proceeding in orderly fashion down the stairs at either end of the building.

3.1.10 Prohibited Items and Restricted Activities

GSI policy prohibits the possession and or use of illegal drugs and alcohol and other controlled substances in the work place, including GSI's facilities and our clients' facilities, and in vehicles owned or rented by GSI. GSI employees may not consume alcoholic beverages during the lunch hour, or during any other break, if they will subsequently be going to a job-site, or operating a company vehicle or other equipment. The substance abuse policy is discussed in Section 7 and the substance abuse program is presented in Appendix A.

In addition, GSI prohibits the possession and or use of firearms or other weapons, fireworks or explosives, or other items which could be used as such, in the workplace,

including GSI and client's facilities. When working on a client's facility, GSI employees must also comply with our client's policies and procedures, which may include prohibitions on such activities as smoking, carrying smoking materials such as cigarettes, matches and lighters onto the facility, radio playing, card playing, reading of newspapers or magazines.

Work-place violence, including fighting and or the making of explicit or implicit threats against any person, is absolutely prohibited and will be grounds for immediate dismissal.

3.1.11 Environmental Compliance

GSI employees are required to abide by all applicable federal, state, and local environmental regulations and our clients' requirements regarding protection of the environment. This includes, but is not limited to, proper management of wastes derived from site investigations or remedial activities such as soil drill cuttings, purged groundwater, and contaminated equipment, preventing spills and discharges, and properly responding to accidental releases. All regulated materials must be managed in a manner appropriate to the material and site, as specified in the project workplan or client's procedures.

Spill containment kits, including sorbent materials, containers, and handling equipment (e.g., shovels) should be available on-site for projects involving potential for release of regulated chemicals or wastes. On projects where groundwater containing hazardous constituents or hazardous waste is being managed, the CERCLA reportable quantities of the specific substances should be specified in the workplan and an attempt made to quantify the volume of released material.

In the event of an accidental spill, project-specific response actions, including containment or abatement and reporting must be followed. Unless otherwise directed, a spill should be reported as soon as possible to the SSO, who will then report to the designated client contact and GSI Safety Administrator.

3.2 Heat Stress/Cold Exposure

3.2.1 Heat Stress and Sun Exposure

Heat stress can be a major hazard during much of the year in southern climes, particularly for workers wearing personal protective equipment (PPE). The material that protects worker from chemical hazards can also evaporation of perspiration and prevent dissipation of body heat. In addition, the use of PPE increases energy expenditure to perform a given task. Depending on the ambient temperature, physical condition of the individual, and work conditions, heat stress can occur very rapidly (within 15 minutes). Excessive sun exposure, particularly on the arms, face, and neck, can contribute to skin damage.

The major varieties of heat-related disorders, their related symptoms and appropriate treatment are listed below in order of increasing severity.

Condition & Related Symptoms	Heat Stress	Heat Exhaustion or Heat Syncope	Heat Stroke
Cramping	May be present	May be present	Absent
Mental State	Faint, dizzy, fatigue	May be disoriented	Stupor or coma
Skin & Complexion	Cool, moist, flush; rash may be present.	Cool, pale, moist	Red, hot, dry
Temperature	Normal	Normal to low	Very high (>105° F)
Pulse	Rapid (>110 beat /min)	Rapid, weak	Rapid, bounding
Blood Pressure	May be low	May be low	May be high in early stages
Treatment	Give water & electrolytes, loosen or remove clothing, move to shade	Give water & electrolytes, loosen or remove clothing, move to shade	Provide rapid cooling by immersion; cover in wet cloth and transport to emergency room

Prevention Measures: All heat disorders are caused by loss of fluids and the body's inability to cool itself. Heat stress is preventable. The following measures should be taken by all workers:

- Maintain a general level of good health and physical fitness.
- Pre-hydrate before going into the field: water or water-electrolyte drinks are preferable to caffeinated beverages or soft drinks. Refrain from alcohol the night before field work.
- While in the field drink frequently. Numerous small drinks at a tepid temperature are better than rapid, large volume intakes of iced drinks.
- Be aware of warning signs such as fatigue, dizziness, faintness or light-headedness, disorientation and report the on-set of symptoms to your supervisor.
- Do not over exert and rest at least a few minutes every hour or two, or more frequently in warm weather.
- Monitor co-workers for signs of heat stress, such as altered complexion, clumsiness or stumbling, or apparent disorientation, and bring their occurrence to the attention of the individual and their supervisor if symptoms appear.

In addition, the SSO should take the following measures:

- Plan the job to prevent heat exposure: to the extent feasible, schedule tasks to take advantage of available shade (e.g., work on the west side of a structure in the AM and on the east side in the PM).
- Try to schedule work so that the most strenuous tasks are not performed during the hottest part of the day.
- Devise a work schedule that provides sufficient time for re-hydration, rest, and heat dissipation and ensure that workers comply.
- Provide sun screen to protect workers from excessive sun exposure.
- Ensure an adequate supply of drinking water is provided.
- Provide a shaded rest area and consider use of fans.
- Monitor workers for signs of heat stress or exhaustion and intervene if they appear to be over-exerting.

3.2.2 Cold Exposure

Cold injuries (including frostbite and hypothermia) and impaired ability to work are two dangers caused by extremely cold conditions. Warning signals include reduced

coordination, drowsiness, impaired judgment, fatigue, and numbing of toes and fingers. Cold exposure can be prevented by appropriate clothing for cold weather work, providing for warm shelter at the work site, and monitoring each worker's physical condition.

3.3 Drilling, Excavation, and Other Heavy Equipment Operations

GSI routinely utilizes the services of subcontract well drillers and other subcontractors supplying equipment and operators for excavation during remediation or construction activities. Special care must be taken to avoid accidents and injuries on projects entailing heavy equipment operations.

3.3.1 Underground and Overhead Utilities Clearance

Prior to any operations involving drilling, subsurface probing, or excavation, drilling or digging locations must be cleared for underground utilities. For most refineries, chemical plants and other major industrial facilities, this is generally done through the host facility. For sites on or near public rights-of-way or power line or pipeline easements, clearance is obtained through organizations such as the Texas Excavation Safety System (TESS: call 1-800-DIG-TESS or use the TESS Fax-a-Locate Service 1-800-690-1291). Locations should be clearly marked with stakes and or paint, and a street address or map showing the locations should be provided at least 2 working days in advance of any drilling or excavation. On plants, if feasible, the site should be inspected in the presence of the site representative. The location of overhead power lines should also be noted relative to drilling or excavation locations and a safe distance (at least 20 ft) maintained between power lines and the drillrig mast or excavation equipment.

3.3.2 Operational Safety

Drilling and other equipment must be in good condition. Particular attention should be paid to the condition of cables and hoisting equipment. The equipment must be equipped with a back-up beeper. Barricades or caution tape should be used as needed to exclude unauthorized personnel from the work area.

During drilling, the drillrig should be positioned to allow for adequate work room and the area kept free of trip and slip hazards. Care must be taken to avoid the catching of loose clothing in moving parts, and to keep hands free of pinch points. Proper PPE including hard hat, safety glasses, gloves, hearing protection, and safety shoes must be worn.

In the event that it becomes necessary to free a stuck cable from the upper portion of the drillrig mast, the mast should be lowered, rather than climbed, if feasible. If it is necessary to climb the mast to make a repair, a harness should be used for fall prevention. In the event of lightning, operations should be suspended, and the mast should be lowered. The geologist's logging table should be situated to face the driller so that operations can be clearly viewed and communication is facilitated.

Acrylic core tubes used for soil sampling can be difficult to handle while cutting open a significant risk of serious laceration can result. A cradle or jig to hold the tube, and a cutting tool specially designed for the tubes are available and should always be used.

3.3.3 Forklift Operations

GSI periodically rents forklifts for movement of drummed investigation-derived wastes, palletized well construction materials, or other heavy items. Only employees who have been trained in fork-lift operations in accordance with §1910.178(l) are permitted to operate forklifts. Before use the equipment must be inspected to ensure proper function.

3.4 Confined Space and Excavation Safety

GSI's activities do not routinely involve entry of personnel into confined spaces such as tanks, vessels, excavations, etc. In the event that a specific project requires entry into a permit-required confined space, assigned personnel will receive proper training prior to project start-up as described in Section 4.

To avoid possible hazards associated with inadvertent confined space entry, GSI employees must obey all posted restrictions on entry to confined spaces, and are expected to know the defining characteristics of a confined space and an entry-permit required confined space: Four defining features of a confined space include: 1) it is not meant to be continuously occupied by workers; 2) it has limited or restricted openings for entry or exit; 3) it has poor natural ventilation; and 4) its size, shape or use may injure workers entering it. A confined space is a permit-required confined space if any of the four characteristics apply: 1) the atmosphere can become IDLH; 2) there is potential for engulfment; 3) its size or shape can trap or asphyxiate; or 4) any other serious recognized safety hazard is present.

Excavations or trenches deeper than 4 ft should not be entered for any purpose unless 1) the excavation walls are properly shored or are sloped at a 1:1 slope, or less steep, and there is no danger of collapse or engulfment; 2) a suitable means of egress such as ramp, stairs or ladder is located so as to require no more than 25 ft of lateral travel to reach it; and 3) testing demonstrates a hazardous atmosphere is not present.

3.5 Chemical Hazards

Hazardous chemicals, including organic and inorganic substances may be present on GSI work-sites as process-related chemicals, managed or uncontrolled wastes, or as residues or contaminants in environmental media. Exposure to elevated levels of hazardous substances can result in injury or illness. Potential routes of entry into the body include 1) inhalation of vapors 2) ingestion of dust, 3) absorption through the skin or eyes, or 4) injection into the bloodstream via a cut, puncture or other wound. Precautions must be taken to prevent exposure to unsafe levels of hazardous chemicals.

The site-specific HASP must identify the hazardous chemicals known or suspected to be present at the site chemicals, and identify their harmful properties and applicable exposure limits. The mode of occurrence in the environment (e.g., sorbed to soil and/or dissolved or as free-phase, in or groundwater), and their known or expected concentrations, based on existing site data, if available, should also be described. As detailed in the Hazard Communication Plan (Appendix C) Material Safety Data Sheets (MSDS) limits should be obtained for the constituents of concern (COCs) and reviewed to ensure an understanding of the nature of the hazard associated with each COC and hazard avoidance measures including for applicable exposure pathways, permissible

exposure limits, and proper identification and use of personal protective equipment. The MSDSs for the primary COCs should be attached to the SS HASP and available on-site.

3.6 Reporting of Safety Concerns and Incident/Accident Investigation

GSI employees are required to report unsafe conditions or activities, and are encouraged to provide recommendations for the upgrade of safety practices. All project-related safety concerns and/or accidents are to be reported immediately to the designated Project Safety Officer or acting designee, who will in turn, report them to the designated client representative and GSI Safety Administrator. In addition to more serious injuries and accidents, reportable safety concerns include, but are not limited to, unsafe physical conditions at the a host facility, unsafe work practices, minor injuries requiring first-aid, and "near misses" (i.e., incidents in which, while no accident or injury may have occurred, an unsafe condition or action resulted in a narrowly averted accident or injury).

Non-project safety concerns and/or accidents (e.g., automobile accidents or safety concerns in the GSI office or warehouse) are to be reported directly to the GSI Safety Administrator.

Injuries and illnesses meeting the criteria for recordable incidents will be recorded on the OSHA 200 Log in accordance with the instructions included on the OSHA 200 form. OSHA Form 101, Supplemental Report of Occupational Injury or Illness will also be completed for all recordable incidents. As required by law, the OSHA 200 log for the most recently completed year is posted in a visible location at the GSI office from February 1 to March 1. OSHA 200 logs and Form 101 are kept on file in the office of the Safety Administrator for a minimum of 5 years as required by law.

All accidents or other safety-related incidents will be investigated by the GSI Safety Administrator or his designee, and will include participation by participants, witnesses, and other personnel, as appropriate. If an incident occurs on a host facility, the investigation will be conducted in accordance with the requirements of host facility as well as with GSI practice. Incident/accident reports will be based on interviews with all persons directly or indirectly involved in the incident and with all eye-witnesses, if any. The report will include a description of events, an analysis of the immediate and root causes of the incident, and recommended action items for prevention of recurrence or similar occurrences. Copies of the reports will be kept on file at GSI offices and will be made available to the host facility owner, if applicable.

4.0 HEALTH AND SAFETY TRAINING PROGRAM

4.1 OSHA "HAZWOPER" Safety Training

All GSI field personnel whose jobs require field work on sites with potential exposure to hazardous chemicals are required to complete a 40-hour training course on safety and health on hazardous waste operations and emergency response (Hawoper), and an annual 8-hour refresher course as required by 29 CFR 1910.120. Key elements of the course include:

- Hazard identification and emergency response;
- Air quality monitoring techniques;

- Proper selection, use, and maintenance of personal protective equipment, including respiratory protection; and
- Decontamination procedures.

All field personnel who perform work in a supervisory role, including directing the activities of subcontract personnel will also complete the 8-hour supervisors training specified by 29 CFR 1910.120.

GSI requires that its subcontractors whose tasks involve potential exposure to hazardous materials also receive the 40-hours training and 8-hour refresher courses as required.

Field workers shall receive a minimum of 24 hours of on the job field training under the direct supervision of the safety officer or other qualified person. Additional training shall be provided as specified in the site-specific health and safety plans.

4.2 Safety Meetings

Company-wide safety meetings for field personnel shall be held at least every six months, typically in conjunction with the OSHA HAZOPER Refresher training which is conducted in-house at GSI's office, twice annually. Additional safety briefings may be conducted at periodic staff meetings. Memoranda or emails will be periodically sent to all staff to call attention to specific safety concerns or procedures.

Project safety orientation meetings for GSI employees and subcontractors shall be conducted prior to project start-up. Informal "tailgate" safety meetings shall be held weekly, or at more frequent intervals as project tasks, personnel, or site conditions change. Safety meeting attendance and topics will be documented on appropriate safety forms.

4.3 Hazard Communication "HAZCOM" Program

GSI has implemented a Hazard Communication (Hazcom) Program in conformance with 29 CFR §1910.1200. This program is presented in Attachment C to this Plan. All GSI employees are oriented to the program upon employment. Refresher classes are conducted annually for all employees, in conjunction with the in-house OSHA HAZWOPER Refresher class. The key elements of the Hazcom program are summarized below.

Material Safety Data Sheets (MSDS) are required for all hazardous materials used in the shop or field. The person purchasing or authorizing the purchase of any chemical has the responsibility to obtain an MSDS from the manufacturer or vendor of the chemical and to provide it to the Safety Administrator.

The Safety Administrator is responsible for maintaining a file of all MSDSs at the GSI main office and shop for the use of employees handling the materials. The Safety Administrator is responsible for maintaining an inventory of all chemicals used in the office, shop, or field.

Hazardous materials used by GSI shall be properly labeled, handled, and stored in accordance with the manufacturer's instructions. Flammable materials shall be kept in a closed metal cabinet equipped with a sign clearly indicating its contents.

To the extent feasible, MSDS shall be obtained for hazardous materials which may be present in the soil, groundwater, or other media at particular sites where drilling, sampling, or excavating shall occur. These MSDSs shall be included as attachments to site-specific health and safety plans, and shall be on file at the project field office, where applicable.

When feasible, the primary source for these MSDS should be the host facility owner. Secondary source include published references such as the Chemical Hazard Response Information System (CHRIS) Manuals, compiled by the U.S. Coast Guard. Copies of the CHRIS Manuals are available in the GSI library.

4.4 Energy Isolation (Lock-out/Tag-out) Program

GSI has developed an energy isolation (Lock-out/Tag-out) program to prevent the accidental exposure to hazardous energy. This program is included as Appendix D to the GSI HASP. Detailed training in lock-out/tag-out procedures will be provided to all employees engaged in tasks requiring energy isolation, and lock-out devices will be assigned to them. All employees are required to be familiar with and abide by general lock-out-tag out principles and procedures as described in the GSI plan.

4.5 Site-Specific Training

Most GSI projects will require site-specific training, which may be supplied on-site directly by the site owner, or through a designated local organization such as Houston Area Contractor Safety Council (HACSC) or Contractor Safety Council of Texas City (CSC/TC). Many sites will also require general worker safety training and certification as offered by the local safety council. GSI project team leaders are responsible for coordinating with the site owner or designated representative to ensure that all personnel (including subcontractors) receive required site-specific training.

4.6 Confined Space Entry Training

GSI's activities do not routinely involve entry of personnel into confined spaces such as tanks, vessels, excavations, etc. In the event that a specific project requires entry into a permit required confined space, assigned personnel will receive proper training prior to project start-up. Training in accordance with OSHA requirements will be provided through a qualified organization such as HACSC or CSC/TC.

4.7 Other Specialized Training

Additional training may be required and will be supplied for personnel involved in certain other activities as required by specific projects. Examples include training for scaffold safety and forklift operation. Training in accordance with OSHA requirements will be provided through a qualified organization such as local contractor safety councils.

5.0 PERSONAL PROTECTIVE EQUIPMENT PROGRAM

5.1 PPE Selection and Use

5.1.1 General

Selection of personal protective equipment (PPE) shall be based on the tasks to be performed and the potential for worker exposure to the hazards identified during the site evaluation phase of the work program, and must always meet or exceed the host facility's minimum requirements. PPE requirements shall be selected or approved by the project safety officer, and detailed in the site-specific health and safety plan. GSI will provide all necessary PPE to its employees at GSI's expense. All PPE is to be used and maintained in accordance with the manufacturer's instructions.

In general, field tasks require a minimum of Level D protection which shall consist of body covering, including long pants, shirt with sleeves, steel-toed boots; hard hat, and safety glasses with side shields. Protective gloves are to be worn when handling abrasive or sharp materials or chemical substances. Basic Level D PPE will be augmented as appropriate to job or site conditions. The project safety officer is responsible for specifying PPE in the site-specific health and safety plan. The following guidelines should be observed.

5.1.2 Respiratory Protection

The GSI Respiratory Protection Program is presented in Section 6.0.

5.1.3 Hand and Body Covering

Disposable, chemical-resistant coveralls made of Tyvek or other equivalent material should be worn during tasks involving potential contact with contaminated soils or other materials, e.g., soil sampling. Poly-coat Tyvek or equivalent should be worn when there is a potential for splashing with free-phase chemical liquids or water with elevated concentrations of dissolved hazardous constituents, e.g., during well development. Other special equipment, such as rubber aprons or slickers should be worn whenever acids or other corrosive or caustic materials are in use as during well development operations. Flame retardant clothing (FRC) or Nomex must be worn as required by host facilities.

Gloves shall be selected for resistance to the anticipated chemical hazards. At a minimum, an inner, latex or vinyl surgical-type glove should always be worn when there is any potential exposure to chemicals. Additional layers of surgical gloves may be worn when potential for chemical exposure is low and when dexterity is required, (e.g., during soil core logging). When the potential for chemical exposure is greater, gloves of nitrile, neoprene, or other chemical-resistant material should be worn over the inner gloves. Coverall cuffs shall be taped to gloves and boots, as appropriate to prevent skin exposure to hazardous liquids.

5.1.4 Head Protection

Hard hats meeting ANSI Z89.1-1986 standards must be worn in areas where vertical clearance is limited, when there is potential for falling objects or other impacts, and during all operations involving heavy equipment.

5.1.5 Eye and Face Protection

Safety glasses with side shields meeting ANSI Z87.1-1989 standards should be augmented with chemical protective goggles on sites where there is potential for chemical exposure. Face shields are required during operations with potential for splashing or spraying with chemicals or contaminated water, such as well acidification or pressure washing of contaminated equipment, and during operations involving the use of grinders or similar equipment.

5.1.6 Hearing Protection

During operations involving elevated noise levels and/or operations located in areas where noise levels may be high, hearing protection shall be worn. Hearing protection must be worn in areas of host facilities designated as high noise areas or hearing conservation areas. Hearing protection devices must be used during work around drilling rigs, excavation equipment, gasoline or diesel-powered pumps and generators, and other high noise equipment, and in designated areas of GSI customer properties. Acceptable devices include earplugs and ear muffs.

5.1.7 Foot Protection

Steel-toed boots made of rubber, PVC, or other chemical resistant material should be worn whenever there is potential exposure to liquid chemicals or non-aqueous phase liquids. Leather boots are acceptable if no significant potential exists for chemical contamination. Rubber boot covers may be worn over leather boots to prevent chemical exposure.

5.1.8 Hand Protection

Employees are required to wear gloves when hands are exposed to hazards such as chemical absorption by the skin, chemical or thermal burns, serious cuts, abrasions, lacerations or punctures. The compatibility of the glove material with the potential chemical or other hazard must be confirmed when preparing the site-specific HASP.

5.2 Inspection, Decontamination, Maintenance, and Storage

Employees are responsible for ensuring that the PPE issued to them is in proper working order. Non-disposable PPE (e.g. respirators, hard hats, etc.) will be inspected by the employee prior to each use, and will be properly decontaminated, stored and maintained. GSI will provide replacement equipment as needed, but it is the responsibility of the employee to inspect the equipment and request replacement as needed.

5.3 Training

Training in the selection, use, and maintenance of PPE will be conducted as part of the 40-hour OSHA Hazwoper training and annual refresher course specified in Section 4.1, above. Initial training may also be provided through contractor safety councils. Additional refresher sessions will be conducted as needed during site-specific orientation sessions.

6.0 RESPIRATORY PROTECTION PROGRAM

The respiratory system offers a significant potential entry point to the body for many organic and inorganic toxic substances via inhalation of dust, fumes, vapors and mists. In addition, the presence of air contaminants can result in an oxygen deficient IDLH condition. To prevent injury or disease of the respiratory system or asphyxiation, GSI has implemented a respiratory protection program which incorporates monitoring, engineering control measures, and use of respiratory protective equipment in.

6.1 Air Monitoring

Identification and quantification of airborne chemicals is required to ensure worker safety. The goals of the air monitoring program are to:

- Determine the level of personal protective equipment that is required;
- Define areas where controls or respiratory protection is necessary; and
- Determine whether exposure potential may indicate the need for medical monitoring.

A description of the instruments and monitoring procedures and the mechanism for using air monitoring information are provided below.

6.1.1 Air Monitoring Techniques and Instruments

Identification and quantification of airborne contaminants is achieved by using direct reading instruments or chemical detection methods. Depending on the nature of the site, these tools are either used alone or in combination. Three primary air monitoring devices are described below:

Organic Vapor Analyzer (OVA Meter)

- Hazard Monitored: Organic gases and vapors.
- Information Provided: On-site detection and quantification of organic gases and vapors.
- Primary use: Continuous or periodic on-site air monitoring for total airborne organics. Indicates if action level is exceeded, necessitating an upgrade in personal protective equipment or a modification of work procedures.
- Detection Method: Flame ionization detector. Gases and vapors are ionized in a flame, producing a current proportional to the number of carbon atoms present.
- Limitations: Does not detect inorganic gases or vapors. Does not identify specific organic compounds.
- Care and maintenance: Requires charged battery, fuel supply, and periodic calibration.

Draeger Tubes

- Hazard Monitored: Specific organic gases and vapors.
- Information Provided: On-site and rapid identification and quantification of specific gases and vapors.

- Primary use: Identification and limited quantification of specific organic constituents at job site.
- Detection Method: Chemical reaction in indicator tube, producing a stain whose length is proportional to the compound's concentration.
- Limitations: Relatively low precision and accuracy. Some interferences can cause misleading results.
- Care and maintenance: Requires fresh indicator tubes.

Chemical Exposure Badges

- Hazard Monitored: Specific organic gases and vapors.
- Information Provided: Average concentrations of specific gases and vapors over an extended period of time.
- Primary use: Monitors average exposure of worker over an extended work period (days or weeks).
- Detection Method: If exposure occurs, chemical is adsorbed onto badge. Time-weighted average concentration of chemical is determined by laboratory analysis of chemical mass and knowledge of total exposure duration.
- Limitations: Relatively low precision and accuracy; extended time period before results are available limits use to relatively long-term exposure evaluation.
- Care and maintenance: Requires fresh indicator badges, proper badge handling and chain-of-custody procedures.

6.1.2 Utilization of Air Monitoring Information

Air monitoring information is compared against designated action levels to determine the level of personal protective equipment that is required. Action levels are developed in the site specific safety plan based on the following considerations:

- Anticipated or suspected gases and vapors at the site;
- Concentrations of hazardous substances expected in environmental media (e.g., soil or water samples);
- Relative concentration and volatility of components in chemical mixtures;
- Toxicity characteristics of the gases and vapors of concern;
- Warning properties of the gases and vapors of concern; and
- Potential exposure of workers during each phase of the work program.

When monitoring for action levels, a conservative assumption is frequently made that all detected vapors represent the specific chemical of concern (COC) with the lowest permissible exposure limit. Unless more specific information is available concerning the contaminant mixture, this is a reasonable assumption. However, this may result in unnecessary use of respiratory equipment which can increase physical stress on the worker, and so should be avoided, especially in hot weather conditions. The action level may be adjusted based on prior sampling data which indicates the relative proportions of various COCs and their properties such as volatility, toxicity, etc. In setting an action level, the goal should be to ensure that workers are not exposed to COC concentrations exceeding permissible exposure levels without respiratory protection, while at the same time not triggering unnecessary respirator use.

If sustained elevated concentrations above the action level specified in the site-specific health and safety plan are detected in the breathing zone (for a period of time specified in the site-specific health and safety plan) by the OVA meter, or if Draeger Tube analyses indicate concentrations above the designated action level, controls must be implemented or personal protective equipment must be upgraded as designated in the site specific safety plan to provide adequate worker protection for the chemical of concern. Otherwise, field work must be suspended or modified to reduce potential exposure to the chemical of concern.

The procedure described above is a general approach which is applicable to common volatile organic compounds encountered in the field. However, a site-specific air monitoring program must be developed for each project based upon the conditions anticipated or encountered at the field location.

6.2 Engineering Controls

The use of respiratory protective equipment such as air-purifying respirators places stress on the body, especially during physical labor performed in hot weather and while wearing protective clothing. In addition, respirators may make verbal communication more difficult, especially in high noise areas. Therefore, whenever feasible, engineering controls and work practice adjustments should be used to reduce exposure to air-borne contaminants. In some cases, a simple adjustment, such as maintaining a position upwind of the contaminant source may be all that is needed to prevent inhalation of air-borne contaminants. Use of fans should also be considered to move vapors away from the workers breathing zone. In some cases, plastic sheeting or other coverings may be placed over affected soil or waste to minimize volatilization to the breathing zone.

6.3 Respiratory Protective Equipment

Use of air-purifying (Level C PPE) or supplied air respirators (Level B PPE) will be based on air quality monitoring as specified in the site-specific health and safety plan. Respirators meeting applicable American National Standards Institute (ANSI) standards shall be provided by GSI and used in accordance with the manufacturer's instructions. Employees will be issued their own respirators for their exclusive use and will be responsible for keeping them clean and in good working order.

6.3.1 Fitness for Use of Respirators

Employees must demonstrate annually that they are fit to wear a respirator by successfully passing a pulmonary function test, administered as part of the medical monitoring program (see Section 7.0, below), and obtaining a physician's written opinion that the employee is fit to use a respirator. More frequent pulmonary function testing may be required depending on the employee's medical history. If, based on the pulmonary function test or other factors, the physician's written opinion indicates that the individual is not fit to wear a negative-pressure air-purifying respirator, use of a positive pressure device may be specified instead.

6.3.2 Approved Devices

Air-Purifying Respirators. Air-purifying respirators (Level C PPE), will be based on air quality monitoring as specified in the site-specific health and safety plan. Respirators

approved by the American National Standards Institute (ANSI) shall be provided by GSI and used in accordance with the manufacturer's instructions. Air-purifying respirators may not be used in oxygen deficient or other IDLH environments.

All employees who will wear respirators will receive training in their use and must be judged fit to use a respirator based on an annual medical examination which includes a pulmonary function test. Workers must have passed a quantitative respirator fit test for the specific make and model respirator (Section 6.4, below). Fit testing is conducted annually. Selection of a full or half-face respirator or powered air-purifying respirator equipped with the appropriate cartridge shall be based on the chemical hazards identified during site evaluation and atmospheric concentrations measured during the air monitoring program. Positive and negative pressure tests shall be performed to ascertain a proper fit.

Half-face mask and full-face piece respirators are issued to all field personnel. Half-mask respirators typically have an assigned protection factor (APF) of 10, meaning they should not be used if the contaminant concentration in air is 10 times the permissible exposure level of the constituent of concern. Full-face piece respirators typically have an APF of 50. Therefore, if the COC concentration in air is close to or above 10 times the PEL, a full-face respirator should be used, and in the event that the COC concentration approaches 50 times the PEL, supplied air should be specified. As a conservative measure, the site-specific plan should generally specify more conservative action levels corresponding to between 0.5 and 0.8 times the APF to allow for uncertainty regarding the composition of the air contaminant mixture. Some COCs may be particularly irritating to the eyes even at concentrations for which half-mask respirators are fully protective of the respiratory tract. In such cases full-face piece respirators are more appropriate.

Appropriate cartridges must be specified, based on the composition of the contaminant mixture. The cartridges must be used in accordance with the manufacturer's instructions including compliance with the specified service life. Typical service life does not exceed 8 hours from opening of the sealed package and may be shorter in the event of high humidity or elevated contaminant concentration.

Supplied Air Respirators. Use of supplied air (Level B PPE), when performed, will utilize equipment from a supplier meeting all applicable guidelines. The equipment will consist of an approved source of breathing-air, airlines, properly designed face pieces and a 5-minute escape bottle. The equipment will be inspected thoroughly before use by the project safety officer or other qualified person, and procedures for use will be reviewed with project personnel prior to project start-up.

At a minimum, supplied air will be certified to conform to Grade D breathing air specifications per ANSI/Compressed Gas Association Commodity Specification for Air G-7.1-1989, (see 29 CFR §1910.134(i)) and to be provided in containers meeting DOT Container Specification Regulations.

6.3.3 Training

Training in the selection, use, and maintenance of PPE will be conducted as part of the 40-hour OSHA Hazwoper training and annual refreshers course specified in Section 4.1, above. Initial training may also be provided through contractor safety councils. Additional

refresher sessions will be conducted as needed during site-specific orientation sessions and the 8-hour OSHA HAZWOPER refresher course..

6.3.4 Fit-Testing

All field employees shall have a passed a quantitative respirator test for the make and model of respirator they will be using. Tests will be performed annually by a qualified analyst under applicable OSHA guidelines. To ensure a proper fit, facial hair in the area of the seal must be shaved.

6.3.5 Respirator Use

To don the respirator, the straps are loosened and pulled to the front of the mask so that the mask seal is unobstructed. The face piece is then placed against the face and the straps are pulled over the head and into place. The straps are then lightly tightened sequentially from top to bottom, and then, once the separator is in place, the straps are re-tightened to provide a snug fit to the face without over-tightening to cause discomfort or constriction.

A seal check is then performed by first placing the hands over the cartridges and inhaling. The mask should contract toward the face and no leakage should be felt along the seal. If a leak is detected, the straps are adjusted and the process is repeated until a good seal is obtained. A hand is then placed over the exhalation vent and the wearer exhales. The mask should be pushed away from the face without breaking the seal. Again, if a leak is detected the straps are adjusted and the test is repeated.

During use, if a leak is detected, the wearer should leave the affected area, remove outer gloves, and make adjustments as needed to obtain a good fit. At the end of the use period, the wearer should leave the affected area, remove outer gloves and, retaining the inner gloves, remove the respirator by first loosening the straps and pulling them over the head with one hand while holding the face-piece with the other.

6.3.6 Inspection, Decontamination, Maintenance, and Storage

Respirators will be inspected by the employee prior to each use, and will be properly decontaminated, stored and maintained. Following use, the cartridges should be removed and discarded, the respirator should be cleaned with a suitable disinfectant cleaner, or with mild detergent and warm water solution, thoroughly rinsed in warm clear water, hand dried with a soft lint-free cloth, and placed in a clean protective casing such as a plastic bag, and stored out of the elements.

Employees are responsible for ensuring that the PPE issued to them is in proper working order. GSI will provide replacement equipment as needed, but it is the responsibility of the employee to inspect the equipment and request replacement as needed.

7.0 MEDICAL SURVEILLANCE

7.1 Applicability

The GSI medical surveillance program is designed to help assess and monitor the health and fitness of all employees who work with hazardous substances. The following employees are required to participate in the program:

- All employees who participate in field work for 30 days per year or greater at sites where hazardous materials are known to be present;
- Workers who are exposed to unexpected or emergency releases of hazardous materials above exposure limits or who show signs, symptoms, or illness that may have resulted from exposure to hazardous substances; and
- Other employees as designated by GSI.

7.2 Elements of Medical Surveillance

A medical exam will be conducted under the supervision of a licensed physician, without cost to the employee, and without loss of pay. The examination will consist of the following procedures and analytical tests:

- A medical and work history;
- General physical examination;
- Blood chemistry;
- Urine analysis;
- Blood temperature and pressure;
- Pulmonary function;
- Chest x-ray;
- Vision test; and
- Hearing test.

GSI will provide the employee with a copy of the results of the examination and any written opinions furnished by the examining physician. Any conditions that may be related to exposure to hazardous substances will be reported immediately to the employee. The physician will not reveal to GSI specific findings, diagnoses, or opinions unrelated to employment.

7.3 Frequency of Medical Examination

The medical examination will be performed according to the following schedule:

- Prior to job assignment;
- Annually after beginning work;
- As deemed necessary by the examining physician;
- As soon as possible for employees injured or becoming ill from exposure to hazardous substances during an emergency, or who develop symptoms of overexposure from hazardous substances; and
- At the termination of employment (if the employee has not had an examination within the last 6 months).

7.4 Records of Medical Examination

Records of medical examination, including the Physician's Written Opinion form are provided by the examining physician to the Safety Administrator under a confidential seal. A copy of the records are provided to the employee and the original is retained in a locked file located in the office of Safety Administrator. Records of medical examinations will be maintained for a period of 30 years.

It is GSI policy that the contents of employees' medical records are confidential and are therefore not examined by the Safety Administrator or other GSI personnel, unless required by specific circumstances. However, the Safety Administrator does review the Physician's Written Opinion form to determine whether any limitations on work assignments or use of personal protective equipment (PPE) are appropriate. If the review of this document indicates that the examining physician has not certified that the employee is fit to wear a respirator, that limitations on the use of PPE are recommended, or that follow-up examination or re-testing is recommended, the employee is so notified, and encouraged to schedule appropriate follow-up as soon as feasible.

7.5 Drugs, Alcohol, and Other Prohibited Items

The GSI policy regarding substance abuse and its prevention is summarized in the "Company Policy Regarding Drugs, Alcohol, and Other Prohibited Items" (see Attachment A). This document presents the GSI company policy regarding substance abuse and provides details regarding the administration of the drug abuse prevention program.

8.0 VEHICLE SAFETY PROGRAM

In order to promote safe driving practices for all employees, GSI has developed a vehicle safety program. A written copy of this program is included as Attachment B.

9.0 RECORD KEEPING

GSI employees will be given a copy of their written medical examination report when a copy of such report is received by GSI. In addition, GSI will retain all medical records on file. OSHA 200 logs and Form 101 will be maintained on file a minimum of 5 years and posted in accordance with the instructions included on the OSHA 200 form. OSHA HAZWOPER training records, respirator fit-test records for each employee are maintained by the Safety Administrator for a minimum of 5 years following termination of employment. Records of medical surveillance are maintained for 30 years.

Daily Site Safety Records and Tailgate Safety Meeting forms must be completed on all field projects and must be placed in the project file. Project safety records will be kept on file for a minimum period of three years following completion of the project.

10.0 SITE-SPECIFIC SAFETY AND HEALTH PROGRAM

10.1 Applicability

Site-specific health and safety plans shall be prepared for 1) projects which require the use of drillrigs, backhoes, or other heavy equipment, 2) projects which require the collection of samples of soil, water, or other media containing potentially harmful concentrations of hazardous materials, and/or 3) projects where site conditions pose a significant risk to human health and safety. Prior to project start-up, the project scope of work and available site data shall be evaluated to determine the specific requirements for a site-specific health and safety plan. It is the responsibility of the Project Team Leader (PTL) to ensure the site-specific HASP is prepared, though the actual preparation may be performed by a designee of the PTL. All site-specific HASPS are subject to review and approval by the SGI Safety Administrator.

The health and safety representative for the host facility will be contacted and a copy of the host facility health and safety plan, contractor health and safety guidelines, or equivalent must be obtained and evaluated in order to incorporate all relevant portions of the host facility plan into the GSI site-specific plan. Review of the GSI site-specific plan by the host facility representative is conducted at the discretion of the host facility project manager or authorized representative. The following paragraphs detail the elements to be addressed by or included in the site-specific health and safety plan.

Site-specific health and safety plans must be kept on-site at all times when work is being conducted and available to all employees and subcontract personnel. Prior to commencement of work, the site-safety officer or other person designated by the project manager or project team leader, will conduct an orientation to the plan for the project field team. All site personnel must sign the coversheet to the plan certifying their understanding of the project health and safety requirements and their agreement to abide by the plan.

As allowed under OSHA regulations (29 CFR 1910.120) the site-specific health and safety plan "need not repeat the employer's standard operating procedures." GSI has developed a site-specific health and safety plan form, provided in Appendix E, which may

be used in conjunction with the this plan. The GSI HASP may be referred to for specific procedures for monitoring, selection and use of personal protective equipment, personnel training, and other required elements of the site-specific plan. When used in this manner, a copy of this document must also be on-site with the site-specific plan and available to all site workers.

10.2 Site Evaluation and Job Safety Analysis

For projects requiring a site-specific health and safety plan, a job safety analysis, or JSA, shall be performed in order to provide the information necessary to eliminate or effectively control anticipated health and safety hazards. Available information regarding the presence, use, storage and/or disposal of hazardous materials shall be collected and reviewed. The scope of work shall be reviewed to identify specific tasks which may pose the risk of injury or chemical exposure to project personnel. A reconnaissance shall be performed by the designated project safety officer or other qualified person, as needed to provide information on current site conditions. Critical elements of the site evaluation include:

- Location and size of the site, topography, structures, accessibility, manufacturing or other operations or processes which could affect the safe implementation of the work;
- Suspected presence of conditions immediately dangerous to life and health (IDLH);
- Identification of potential hazards, including physical, chemical, and biological hazards; and
- Location, phone numbers and maps to the nearest emergency medical facilities.

The initial site evaluation must include an assessment of the possible presence of Highly Hazardous Chemicals at quantities above applicable Threshold Quantities identified in 29 CFR §1910.119. The client health and safety representative should be contacted to 1) determine whether such materials are present, 2) obtain material safety data sheets and other appropriate information, and 3) identify and make arrangements for any specific training which may be required for work in and around the unit or area, including procedures in the event of an accidental release of materials to the environment.

10.3 Elements of the Site-Specific Health and Safety Program

The site-specific health and safety plan shall include the following elements. The specific organization of the plan may be varied:

- **Project Description:** An introductory section shall provide a summary of the project objectives, tasks, location and generalized project schedule.
- **Site Description:** The description shall include a physical description of the site and the identification of potential physical, chemical and biological hazards. If feasible, a site map should be included.

- **Emergency Procedures:** Emergency procedures must be specified, including any alarm signals, emergency contact information, location of assembly areas
- **Project Organization, Personnel, and Training:** This section identifies key project personnel, training requirements and other qualifications for site workers.
- **Potential Hazards and Hazard control Measures:** This section identifies potential hazards, including physical and chemical hazards, and measures to mitigate or avoid hazards, including site controls, utility clearance, and safe work practices.
- **Air Quality Monitoring:** This section specifies monitoring instrumentation and methods to prevent exposure to air-borne contaminants.
- **Personal Protective Equipment:** This section specifies basic PPE requirements and conditions for PPE upgrades, including action levels and specifications for use of respiratory protection. \
- **Decontamination:** Procedures for decontamination of personnel and equipment are be specified. Where the possibility of a spill of hazardous materials exists, a list of the equipment to be present on site and the procedures for responding to a spill will be specified in this section.
- **Safety Plan Distribution and Compliance:** GSI requires its employees and subcontractors to read, understand and certify in writing their agreement to comply with all of the rules and regulations contained within the site-specific health and safety plan. Periodic inspection of work sites will be conducted by the Safety Administrator to ensure compliance.



**GROUNDWATER
SERVICES, INC.**

APPENDIX A

COMPANY POLICY REGARDING DRUGS, ALCOHOL, AND OTHER PROHIBITED ITEMS

GSI Health and Safety Plan

Groundwater Services, Inc.
2211 Norfolk, Suite 1000
Houston, Texas 77098
(713) 522-6300

APPENDIX A

COMPANY POLICY REGARDING DRUGS, ALCOHOL, AND OTHER PROHIBITED ITEMS

POLICY STATEMENT

Groundwater Services, Inc. (GSI), is committed to maintaining a safe and productive work environment for all employees and to providing efficient services to our clients. We further recognize the deleterious impact of drug and alcohol abuse on work-place safety, employee performance, and absenteeism. Therefore, to ensure a safe work environment, a drug-abuse prevention program will be implemented to:

- Restrict certain items and substances from being brought on or being present on company property;
- Prohibit GSI employees and all others from reporting to work, working, or being present on company property or at the work site while having detectable levels of certain drugs and other substances in their systems;
- Establish routine testing methods to detect such substances or conditions; and
- Provide assistance to those employees requesting counseling or rehabilitation services.

The provisions of this drug-abuse prevention program are detailed below.

Prohibited Items

The use, possession, sale, manufacture, distribution, dispensation, concealment, receipt, transportation, or being under the influence of any of the following items or substances on GSI property by employees and all others is prohibited:

- **Illegal drugs and controlled substances** including, but not limited to marijuana, cocaine, opiates (i.e. morphine and codeine, phencyclidine, amphetamines, methamphetamines), and any other drugs or substances which will in any way affect safety or job performance.
- **Alcoholic beverages**, except at special functions as specifically authorized by GSI management. Consuming alcoholic beverages while driving any vehicle for company business is prohibited. Alcohol may not be consumed during lunch breaks if the employee will subsequently be returning to work on a client's facility.
- **Drug paraphernalia**
- **Over-the-counter medications**, except those which are taken in accordance with manufacturer's dosage recommendation and which do not restrict an individual's work activity.

- **Prescription drugs**, except those which have been prescribed by an authorized medical practitioner for the person in possession of the drugs and which do not restrict the individual's work activity.

Conditions of Testing

GSI employees will be required to submit to a urine drug test, a breath test, and/or a blood test under the following circumstances:

- **Routine Drug Testing:** GSI requires mandatory urine drug testing for all GSI employees on at least an annual basis. This drug testing will be conducted in conjunction with annual physical examination required of all employees. Additional testing may be conducted as required for entry on client property.
- **Reasonable Suspicion:** An employee will be subject to testing for sub-stance use when there is reasonable suspicion that he/she is unable to perform his/her job, or that he/she is under the influence of drugs or alcohol.
- **Pre-Employment:** Offers to prospective employees will be made contingent upon pre-employment urine drug testing and a complete physical examination. Applicants testing positive for drug use will not be hired.
- **Legal or Regulatory Requirements:** Other testing or conditions may be required to comply with local, state, or federal laws, contractual agreements, or regulatory requirements.
- **Client Requirements:** Adoption of drug and alcohol policies or programs of GSI's clients may be required for employees working on specific facilities. GSI clients may require additional testing for entry onto their sites, including random testing upon entry. This may also include inspection and search of vehicles or persons. Employees working on ExxonMobil facilities, must comply with the requirements of the ExxonMobil model Alcohol, Drug, and Contraband Policy in Addendum A.1. Employees working on ExxonMobil sites will be required to sign a form acknowledging their understanding of the policies and consenting to the release of test results.

Drugs to be Tested and Levels of Detection

Urine drug tests shall be run by a certified testing laboratory which uses the best available technology for measuring metabolites of substances entering a person's system. Initial drug tests will employ an enzyme immunoassay technique. All specimens identified by the initial test as positive shall be reanalyzed by a gas chromatography/mass spectrometry (GC/MS) technique for confirmation.

All persons shall have the opportunity, prior to testing, to list all prescription and non-prescription drugs they have used in the last thirty days and to explain the circumstances surrounding the use of such drugs.

Samples will be analyzed for the following substances:

<u>Drug Group</u>	<u>Positive Detection Level (ng/l)</u>	
	<u>Initial Test</u>	<u>Confirmation Test</u>
Amphetamine	1000	
Amphetamine		500
Methamphetamine		500
Cocaine metabolites	300	150
Marijuana metabolites	100	15
Opiate metabolites	300	
Morphine		300
Codeine		300
Phencyclidine	25	25

Testing for additional substances, (e.g., for alcohol) may be required for employees assigned to work on specific facilities. Alcohol testing will be performed on breath, saliva or blood, but not urine samples.

The positive detection levels specified above are subject to change as warranted by advances in technology. (Note: The above detection values are expressed in units of nanograms/liter (ng/l) which is roughly equivalent to 1 part per billion.)

ADMINISTRATION OF THE DRUG ABUSE PREVENTION PROGRAM

The GSI drug-abuse prevention program will be administered by the company President or designated officer. Procedures for employee notification, evaluation of test results, data confidentiality, and disciplinary action are as follows:

- **Employee Notification:** GSI will provide written copies of this policy to all employees. Additional information will be made available regarding the impacts of drug abuse on the workplace and the responsibility of employees and their supervisors under this prevention program. Prior to any drug testing, employees will be requested to sign a consent form authorizing performance of the test and permitting the release of test results to company officials. The consent form will set forth the procedures for confirmation of an initial positive test result, the consequences of a confirmed positive test result, the consequences of refusal to consent to such testing, and related employee rights.
- **Evaluation of Test Results:** GSI will appoint a licensed physician with a knowledge of substance abuse disorders to act as Medical Review Officer (MRO). The duties of the MRO will include evaluation of drug testing procedures, interpretation of test results, and discussion with employees regarding the significance of positive test results and possible alternative explanations.
- **Confidentiality:** All information from an employee's or applicant's drug test is confidential and will be disclosed only to company officials with direct responsibility for the drug-abuse prevention program. Disclosure of test results to any other person, agency, or organization is prohibited unless written authorization is obtained from the employee. All records relating to the taking of a drug test or the order to take a drug test shall be deemed confidential unless written authorization has been obtained from the employee or the records become the

subject of a judicial proceeding. The results of a positive drug test shall not be released until these results are confirmed. The company shall implement procedures to prevent the unauthorized distribution of such information.

- **Disciplinary Actions:** An employee found in violation of any aspect of this policy, or refusing to submit to drug testing or to sign the appropriate consent and chain-of-custody forms shall be subject to termination or disciplinary probation, at the discretion of the company. A second violation of this policy will result in immediate termination from employment.

Any employee who is confirmed to test positive for drug or alcohol use for the first time will be given a choice of rehabilitation or termination from employment. Any employee who is confirmed to test positive for drug or alcohol use for a second time will be terminated from employment. Tampering with lab specimens or procedures in any manner will result in immediate termination of employment for all parties involved.

Any employee who is convicted or pleads guilty or no contest to a legal violation related to drugs or alcohol will be subject to termination and will be required to submit to drug testing prior to returning to work.

EMPLOYEE RIGHTS

The opportunities available to an employee to challenge or explain a confirmed positive drug test will include the right to:

- 1) meet in private with designated company officials,
- 2) obtain a portion of the remaining sample to be independently tested at the employee's expense, and
- 3) procure a second opinion regarding the test findings by a licensed physician with knowledge of substance abuse disorders at the employee's expense.

If an explanation of a positive drug test merits further inquiry, for the duration of the inquiry, the employee will be suspended without pay or returned to work, at the discretion of the company.

REHABILITATION

Rehabilitation may be offered at the request of the employee if the request is unrelated to an identification of the employee as a violator of the policy and the violation does not involve selling or distributing drugs or serious misconduct. The costs of rehabilitation will be paid for by the Company only within the limits of the existing medical benefits program provided to that employee.

Rehabilitation may involve professional counseling on an outpatient basis for employees allowed to remain at work or daily outpatient drug maintenance, hospitalization, or detoxification for employees suspended from work. The company will provide the employee with relevant information, such as the identity of local community resources for the treatment of substance abuse disorders.

Any employee who accepts rehabilitation approved by the company, but fails to complete the prescribed program or to comply with the prescribed after-care, is subject to termination. Upon successful completion of the recommended rehabilitation, the employee will be tested before returning to work. After returning to work, the employee will be subject to periodic drug or alcohol tests until deemed recovered by the Medical Review Officer.

DEFINITIONS

To aid in understanding and administering this policy, the following definitions apply:

Illegal Drugs: drugs which are not legally obtainable and drugs which are legally obtainable but have been obtained illegally.

Controlled Substances: chemical substances and drugs controlled under the laws of the United States of America or by appropriate state law.

Company Property: used in its broadest sense, including all property, facilities, land, parking area, offices, buildings, structures, installations, equipment, vehicles, and any other facilities whether owned, rented, or leased for company use.

Detectable Levels: the measurable presence of an illegal or prohibited drug or substance found in body fluids at levels of detection above the lowest detection level established for the analytical method used in the testing laboratory.

Reasonable Suspicion: a belief based on reasonable, observable, objective, or articulable facts sufficient to lead a prudent supervisor to suspect that the person has been using a prohibited drug, substance, or alcohol.

Under the Influence: being unable to perform work in a safe and productive manner, being in a physical or mental condition which creates a risk to the safety and well-being of the individual, other employees, the public, or to property. Having laboratory evidence of the presence of drugs, alcohol, prohibited or controlled substances, in excess of an identifiable trace quantity in the body.

Possession: actual or constructive care, custody, control, or immediate access.

Drug Paraphernalia: including, but not limited to:

1. Blenders, bowls, containers, spoons, mixing devices used for or intended for use in compounding controlled substances.
2. Capsules, balloons, envelopes and other containers used for or intended for use in concealing or packaging small quantities of controlled substances.
3. Hypodermic syringes, needles, or other objects designed or intended for injecting controlled substances into the human body.
4. Objects used or intended or designed for use in ingesting, inhaling, or otherwise introducing marijuana, hashish, cocaine, or hashish oil into the human body, such as: pipes; water pipes; carburation tubes and devices; smoking and carburation masks; roach clips and other objects used to hold smoking materials; chamber pipes; electrical pipes; air-driver pipes; bongs; ice pipes; and rolling paper not associated specifically with tobacco products.

Metabolite: substance produced by the human body which indicates the presence of an ingested substance.

Nanogram: a normally recognized measure of a metabolite equivalent to .000000001 gram. The unit of 1 nanogram/liter (ng/l) is roughly equivalent to 1 part per billion (ppb).

Immunoassay: a laboratory testing technique to detect trace amounts of a substance in a sample.

Drugs: those to be tested as listed below:

Amphetamines: include three closely related drugs, amphetamine, dextroamphetamine, and methamphetamine. Their street names include: "speed, white crosses, uppers, dexies, bennies, and crystal". In pure form, they are yellowish crystals that are manufactured in tablet or capsule form. Abusers also sniff the crystals or make a solution to be injected.

Prescription medications used for treatment of sleep disorders and for weight control contain benzedrine and dexedrine. Over-the-counter cold medications contain Ephedrine, Pseudoephedrine, or phenylpropanolamine which, if taken in sufficient quantity, can result in positive test results.

Cocaine: is a drug extracted from the leaves of the coca plant which grows in South America. Like the amphetamines, it is a central nervous system stimulant. Cocaine appears in several different forms. Cocaine hydrochloride is the most available form of the drug and is used medically as a local anesthetic. It is usually a fine, white, crystal-like powder, although at times it comes in larger pieces which on the street are called "rocks". Cocaine is usually sniffed or snorted into the nose, although some users inject it or smoke a form of the drug called freebase.

Marijuana: (grass, pot, weed) is the common name for a crude drug made from the plant *Cannabis sativa*. The main mind-altering (psychoactive) ingredient in marijuana is THC (delta-9-tetrahydrocannabinol), but more than 400 other chemicals also are in the plant.

A marijuana "joint" (cigarette) is made from the dried particles of the plant. The amount of THC in the marijuana determines how strong the effects will be.

Opiates: include opium and opium derivatives such as morphine, codeine, and heroine. Methadone is a synthetic opiate with morphine-like properties. Heroin is the main narcotic in this group which is abused. Prescription drugs may also be abused and include paregoric, which contains opium; cough syrups, Percodan, and Tylenol-3, which contain codeine; methadone, meperidine, and morphine.

Phencyclidine: (PCP) is most often called "angel dust". It was first developed as an anesthetic in the 1950's. However, it was taken off the market for human use because it sometimes caused hallucinations. PCP is available in a number of forms. It can be in a pure, white, crystal-like form.

SEVERABILITY OF POLICY PROVISIONS

If any part of this policy is held invalid by a competent authority, such part shall be invalid; however, the remainder shall continue in full force and effect.



**GROUNDWATER
SERVICES, INC.**

APPENDIX B

MOTOR VEHICLE SAFETY AND DEFENSIVE DRIVING PROGRAM

GSI Health and Safety Plan

Groundwater Services, Inc.
2211 Norfolk, Suite 1000
Houston, Texas 77098
(713) 522-6300

APPENDIX B

MOTOR VEHICLE SAFETY AND DEFENSIVE DRIVING PROGRAM

Groundwater Services, Inc. (GSI), is committed to employee safety and the promotion of safe defensive driving practices. Accordingly, GSI has developed a proactive motor vehicle safety and defensive driving program to promote safe driving by all GSI employees. The policy is effective as of October 1, 1991. The tenets of this policy are summarized below.

- **Pre-Employment Screening:** Prior to hiring any employee who will be required to operate a motor vehicle as part of their employment, GSI will obtain and review the most recent available driver record service report for the prospective employee. Employee driving records will be evaluated as part of all hiring decisions for employees required to operate a motor vehicle as part of their employment. In addition, prospective employees with three or greater moving violations within the preceding one-year period will not be eligible for employment with GSI.
- **Monitoring of Employee Driving Practice:** Every sixth months beginning on October 1, 1991, GSI will obtain the most recent available driver record service report for all GSI employees who are required to operate a motor vehicle as part of their employment. These driving records will be reviewed by the safety program administrator and kept on file at GSI. Based upon the review of the driving safety records, employees may be placed on probation and/or required to attend defensive driving instruction, as discussed below.
- **Defensive Driving Instruction:** All new GSI employees who are required to operate a motor vehicle as part of their employment and
 - a) are 25 years of age or younger, or
 - b) have at least one moving violation within the preceding one year period

will be required to attend a Level 1 Driving Safety Awareness Course within one month of beginning employment at GSI. GSI will reimburse the employee for the **first** Level 1 Driving Course, with the employee being responsible for any subsequent courses. Those employees with two or three moving violations within the preceding year will also be required to attend a Level 2 Driving Safety Awareness Course within six weeks of beginning employment at GSI. The Level 1 course is composed of eight hours of classroom instruction, and the Level 2 course is composed of eight hours of classroom instruction and four hours of personalized driving instruction.

During their employment with GSI, any employee who is required to operate a motor vehicle as part of their employment and who accumulates two moving violations (in company or private vehicles) during a one-year period will be required to attend a Level 1 Driving Safety Awareness Course. Those employees who accumulate three moving violations within a one-year period (in company or private vehicles) will also

be required to attend a Level 2 Driving Safety Awareness Course and will be placed on probation. The driving probation program is discussed in more detail below.

- **Employee Probation/Termination:** Any GSI employee who accumulates three or more moving violations within a one-year period will be placed on motor vehicle probation. The terms of probation are as follows:
 - a) Accumulation of a fourth moving violation within a one-year period will result in the employee being barred from operating GSI vehicles. If the fourth moving violation is received while operating a company vehicle, the violation will be considered sufficient grounds for immediate termination, at the discretion of the company.
 - b) The employee will be required to attend the Level 2 Driving Safety Awareness Course. If the employee has already taken the Level 2 course, they will be required to repeat the course.

The period of employee motor vehicle probation ends when sufficient time has elapsed such that the employee has two or fewer moving violations within the preceding one-year period.

- **Alcohol and Drug Abuse Prevention:** All GSI employees are required to comply with the terms of the GSI Policy Regarding Drugs, Alcohol, and Other Prohibited Items (see Attachment A). A Driving While Intoxicated (DWI) conviction of any company employee while operating a company vehicle will result in the immediate termination of the employee.
- **Employee Safety Meetings:** Safe driving practice will be discussed as a part of regular GSI safety meetings.
- **Employee Notification:** Copies of the GSI Motor Vehicle Safety Program are distributed to all employees upon hiring as part of the corporate Health and Safety Plan, or upon substantial revision of the plan. A copy of the policy will be posted in the GSI office.
- **Program Administration:** Administrator of the motor vehicle safety program is the corporate safety administrator Robert Lee.



**GROUNDWATER
SERVICES, INC.**

APPENDIX C

HAZARD COMMUNICATION PROGRAM

29 CFR §1910.1200

GSI Health and Safety Plan

Groundwater Services, Inc.
2211 Norfolk, Suite 1000
Houston, Texas 77098
(713) 522-6300

APPENDIX C

GROUNDWATER SERVICES, INC. HAZARD COMMUNICATION PROGRAM

1.0 INTRODUCTION: PURPOSE AND SCOPE OF GSI HAZCOM PROGRAM

The Groundwater Services, Inc., (GSI) Hazard Communication program has been developed to provide the information necessary to enable employees to perform their jobs in a manner which minimizes the potential for illness or injury due to exposure to hazardous chemicals. The program is designed to comply with the Occupational Safety and Health Administration (OSHA) Hazard Communication Standard (also known as "Employee Right to Know") as specified in 29 CFR §1910.1200. This program applies to all chemical usage in the work place, including the GSI office and warehouse as well as job sites.

This program applies to all GSI employees, and it is the responsibility of each employee to follow the procedures and practices outlined in this plan. In addition, employees who oversee the work of subcontractors at GSI job sites must ensure that subcontract personnel comply with applicable portions of the plan as specified below.

While GSI is not directly involved in chemical manufacturing, importation, or transportation, GSI employees routinely perform work at chemical manufacturing facilities and other sites where a general knowledge of potential chemical hazards is essential. In addition, many projects require the use of chemicals, some of which are hazardous, for tasks such as well development and treatment, field testing of soil and groundwater samples, and other miscellaneous support functions.

The primary potential for chemical exposure for GSI employees is in conjunction with the investigation and remediation of hazardous waste sites. Although hazardous wastes regulated under the Resource Conservation and Recovery Act (RCRA) are explicitly excluded from the application of the Hazcom Standard, the GSI Hazard Communication Program also describes procedures for communication of potential chemical hazards associated with hazardous waste sites.

While home usage of chemicals is not regulated under the Hazcom standard, GSI encourages employees to apply the knowledge they gain in the workplace to the home environment. Family members should be instructed in the safe use and handling of household chemicals, and appropriate precautions should be taken to prevent harmful chemical exposure in the home.

The company safety officer (CSO), is responsible for preparation, implementation, and any needed revision of the GSI Hazard Communication Program. Employees with questions regarding this program should contact the CSO, R.S. Lee.

2.0 MATERIAL SAFETY DATA SHEETS (MSDS)

General Information: A Material Safety Data Sheet (MSDS), is required for each hazardous chemical used in the work place. As discussed in Section 4.0, MSDSs for chemicals encountered in soil and groundwater at hazardous waste sites are also required for preparation of site-specific health and safety plans. The MSDS contains important information on the potential hazards of exposure to the chemical, means of preventing harmful exposure, and appropriate response measures in the event of release or exposure. All employees working with any chemicals, whether in the field, warehouse, or office, should know how to use an MSDS, and should be familiar with the hazards of the particular chemicals with which they work. As specified in 29 CFR §1910.1200(g) the MSDS must contain, at a minimum, the following information:

- the identity of the chemical and any hazardous ingredients;
- physical and chemical characteristics and physical hazards of the chemical;
- health hazards, including whether the chemical is carcinogenic;
- primary routes of entry to the body;
- applicable exposure limits (e.g., PEL, TLV, IDLH, etc.);
- precautions for safe handling and use, and control measures (e.g., personal protective equipment (PPE));
- emergency and first aid procedures; and
- the name, address, and phone number of the preparer of the MSDS and the date of preparation.

Acquisition of MSDSs: When chemicals such as testing reagents, instrument calibration standards, well treatment chemicals, cleaning agents, lubricants, etc., are procured for use in the work place, including the GSI office, warehouse, and/or job site locations, an MSDS must be obtained. The person ordering or purchasing the chemical is responsible for supplying an MSDS to the CSO. Most chemical suppliers routinely provide an MSDS when chemicals are delivered or picked up. However, the individual placing the order must verify that an MSDS will be provided with the chemical. Since the MSDS is frequently sent directly from the supplier to the CSO without explanation, GSI employees who order chemicals for a particular use should, upon ordering, inform the CSO of what chemical has been ordered and from whom, the approximate quantity, and its intended use. A form for this purpose is attached to this plan; additional copies are available from the CSO.

An MSDS must also be obtained for any chemical purchased at hardware or building supply stores or other retail establishments. If the establishment can not provide a copy of the MSDS, the individual making the purchase should contact the manufacturer directly, and have them provide a copy of the MSDS immediately. The MSDS should be consulted prior to use of the chemical. (Note that the manufacturer will frequently include a telephone contact number and/or hazard data on the container label). It is not necessary to obtain an MSDS with every purchase, as long as an MSDS is already on file at GSI.

Location and Distribution of MSDSs: MSDSs for chemicals used in the work place are kept in clearly labeled black and yellow loose-leaf notebooks at two locations: 1) at the GSI office, in the office of the CSO, and 2) at the GSI warehouse in the front office

room. Neither book may be removed from its location, except by special permission of the CSO. The files are arranged alphabetically by the common name of the chemical. When an MSDS is received, it must be routed to the CSO, who will place a copy of the MSDS in the office file and provide a copy for the warehouse file. The warehouse MSDS file is maintained by Ben Medina. Superseded versions of MSDSs must be removed from the books and replaced with the current versions.

At the front of each notebook is a listing of chemicals used by GSI. The list identifies all chemicals currently in use or storage at the GSI office or warehouse, as well as chemicals which have been used in the past and which may be periodically present at either the office or warehouse, or on job sites. The chemical inventory is updated by the CSO upon procurement of additional chemicals. The listing of chemicals is also included in this document as Table 1. Updates to Table 1 of the Hazcom program will be distributed to all employees annually or more frequently, if needed.

On tasks which require the use of hazardous chemicals in the field, such as well development and treatment, field testing of soil and groundwater, equipment decontamination, and the like, the project manager or project safety officer should review the MSDS for the chemical(s) to be used and brief project personnel on their hazards and proper handling and use. A copy of the MSDS should be attached to the project health and safety plan, copies of which must be placed in the job file and carried into the field.

Some GSI clients also require that an MSDS for any material brought on-site be provided to their safety representative. This includes materials brought on-site by our subcontractors. Compliance with this requirement is the responsibility of the project manager.

3.0 CONTAINER LABELING

All hazardous substances received at the work place should be labeled by the manufacturer/distributor with the identity of the chemical and appropriate hazard warnings. These labels must not be removed from the container, or defaced. If the contents are to be placed in other containers for storage or use, (e.g., if a relatively large quantity of the material is to be placed in several smaller containers for use in the field) the additional containers must all be labeled with the product name and all appropriate hazard warnings.

Portable containers into which hazardous chemicals are transferred from labeled containers do not require labels *only if* they are intended for the immediate use of the employee who performs the transfer. If the chemical is to be stored after the "immediate use" or the container is to be passed on to other employees for their use, the container must be labeled.

4.0 CHEMICALS ENCOUNTERED DURING OPERATIONS AT HAZARDOUS WASTE SITES

As stated in 29 CFR 1910.1200 (b)(6), the Hazcom Standard

"does not apply to : (i) Any hazardous waste as such term is defined by the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act of 1976 as amended (42 U.S.C. 6901 et seq.), when subject to regulations issued under that Act by the Environmental Protection Agency."

However, because hazardous substances encountered in soil and groundwater at hazardous waste sites represent the primary mechanism for potential chemical exposure for GSI employees, this section provides general guidelines for hazard communication applicable to such sites. Additional information is provided in the *GSI Health and Safety Program*.

As described in the *GSI Health and Safety Program*, a site-specific health and safety plans is required on most field projects. The site-specific plan must include information on any known or likely chemical hazards present at the site, and procedures for mitigation of those hazards, (e.g., monitoring, PPE, etc.). The primary source of this information is the MSDS. MSDSs for chemicals of concern at the site should be attached to the site-specific plan and *must be present at the job site* whenever work involving potential for chemical exposure is being performed.

For chemicals encountered in soil and groundwater at hazardous waste sites, an MSDS can frequently be obtained through the facility owner. In addition, the Chemical Hazards Response Information System (CHRIS) Manual, compiled by the U.S. Coast Guard and available in the GSI library, contains hazard data sheets for many chemicals commonly encountered at hazardous waste sites. While these data sheets are not formally designated "MSDS," they do contain all of the required information listed in Section 2.0. It should be noted, however, that the data sheets in the CHRIS Manual were last revised in 1991. Therefore, not all of the information contained on them is current. When preparing a site-specific health and safety plan, more current sources of exposure limit values, such as the annual publication by the ACGIH, *Threshold Limit Values for Chemical Substances and Physical Agents*, or the *Respirator Selection Guide*, published annually by the 3M Company, should be consulted. These can be found in the office of the CSO.

5.0 EMPLOYEE HAZCOM INFORMATION AND TRAINING

A copy of the *GSI Hazard Communication Program* shall be provided to all new employees and an orientation to the program conducted as part of the new-employee orientation. Copies of any revisions to the Hazcom Program, including updates of the chemical inventory shall be provided to all employees upon approval by the CSO. Copies of the plan shall also be kept in the MSDS file notebooks at the GSI office and warehouse. The original is on file in the office of the CSO.

Hazcom refresher training is provided for all field workers, field supervisors, and project managers annually and is mandatory. This training is generally conducted by the GSI CSO in conjunction with the annual Hazwoper refresher class under 29 CFR 1910.120. Hazcom training will include, at a minimum, the following subjects:

- a detailed review of the GSI Hazcom program
- use of the MSDS, including GSI procedures for distribution, etc.
- hazardous chemical properties and chemical hazard recognition
- detection and monitoring methods
- protective measures, such as engineering controls, work practices, and PPE.

Special sessions will be held more frequently for affected employees, as needed, whenever a new chemical hazard is introduced into their work place.



**GROUNDWATER
SERVICES, INC.**

APPENDIX D

**SAFETY PROCEDURE FOR
ELECTRICAL/HAZARDOUS ENERGY LOCKOUT**

29 CFR §1910.147

GSI Health and Safety Plan

Groundwater Services, Inc.
2211 Norfolk, Suite 1000
Houston, Texas 77098
(713) 522-6300

APPENDIX D

SAFETY PROCEDURE FOR ELECTRICAL/HAZARDOUS ENERGY LOCKOUT

Groundwater Services, Inc., Houston, Texas.

1.0 PURPOSE AND SCOPE

1.1 Purpose

This procedure is established to comply with OSHA Regulations (29 CFR §1910.147) concerning control of hazardous energy. The procedure establishes the minimum requirements for the lockout or tag-out of energy isolating devices during maintenance and repair operations. It shall be used to ensure that machines and electrical equipment are isolated from all sources of potentially hazardous energy, and are locked out or tagged out before employees perform service or maintenance activities where the unexpected energizing, startup, or release of stored energy could cause injury.

1.2 Scope

This procedure applies to all employees of Groundwater Services, Inc. (GSI) and their subcontractors involved in the installation, service, and maintenance of powered machinery and equipment. Such equipment currently in use by GSI is limited to electric-powered sump pumps, submersible groundwater pumps, and associated motor control equipment.

Accordingly, this procedure is limited to the lock out of electrical equipment and does not cover the installation or removal of "Blinds," lockout of hydraulic-powered or pneumatic-powered equipment, or lock out of radioactive energy sources. GSI employees and subcontractors are specifically instructed not to enter any vessel or activate any valves or other devices relating to hydraulic, pneumatic, radioactive, or process chemical systems under any circumstance. Should GSI's scope of services be expanded in the future such that access to these types of systems becomes necessary, this procedure will be revised and expanded as appropriate to comply with OSHA standards before such work is performed.

3.0 DEFINITIONS

"Affected employee"

An employee whose job requires him/her to operate or use a machine or electrical equipment on which servicing or maintenance is being performed under lockout or tag-out, or whose job requires him/her to work in an area in which servicing is being performed.

"Authorized employee"

A person who implements a lockout/tag-out system procedure on machines or equipment to perform maintenance or service on that machine or equipment.

"Capable of being locked out"

An energy isolating device is considered capable of being locked out if it is designed with a hasp or other attachment or integral part to which, or through which a lock can be affixed, or if it has a locking mechanism built into it.

Energized

Connected to an energy source or containing residual or stored energy.

"Energy isolating device"

A mechanical device that physically prevents the transmission or release of energy, including, but not limited to the following: a manually operated electrical circuit breaker, a disconnect switch, or a manually operated switch by which the conductors of a circuit can be disconnected from all ungrounded supply conductors.

"Lockout"

Placement of a lockout device on an energy isolation device ensuring that the energy isolating device and the equipment being controlled can not be operated until the lockout device is removed.

"Lockout Device"

A device that utilizes a positive means, such as a keyed lock, to hold an energy isolating device in the safe position and prevent the energizing of a machine or equipment. For the purpose of this procedure, a keyed padlock, color-coded OSHA yellow, identified as a lockout device, and labeled with the name of the owning authorized employee will be used.

"Machinery or Equipment"

As used in this procedure, machinery or equipment refers to any mechanical or electrical device containing or utilizing potentially hazardous energy, including pumps, motors, etc.

"Tie Wrap"

A non-reusable self-locking device, such as a one-piece nylon cable tie, which is attachable by hand and non-releasable with a minimum unlocking strength of 50 pounds.

"Tag-out"

The use of lockout tags and tie wraps on energy sources which can not be locked out. A tag-out is not as secure as a lockout and may only be used when a lockout is not feasible.

3.0 RESPONSIBILITIES:

3.1 GSI Responsibilities

GSI is responsible for preparation of a lockout procedure in conformance with the 29 CFR § 1910.147, including proper training of its authorized and affected employees in that procedure, and for providing an adequate supply of locks and other necessary lockout devices.

3.2 Authorized Employee Responsibilities

The authorized employee is responsible for safe and proper implementation of this lockout procedure (i.e., for preventing accidental operation or energizing of machinery or equipment by proper use of lockout devices).

3.3 Individual/Affected Employee Responsibilities

Persons performing inspection or repair work are responsible for their own safety and protection by having satisfied themselves that the authorized employee has correctly locked out the equipment to be repaired. The authorized employee will assist the individual in reviewing the lockout plan, verifying the lockout, and testing start switches after lockout. It is mandatory that the maintenance and or operations person try the start switch or switches to verify that the proper equipment has been locked out and that there are no additional energy sources.

4.0 POLICY AND PROCEDURES

4.1 Lockout/Tag-out Procedure

Prior to any maintenance or service to be performed on equipment covered by this procedure (i.e., electric sump pumps, submersible groundwater pumps, and associated motor control equipment), the authorized employee will notify all affected employees of the lockout. The equipment will then be shut down and locked out by the authorized employee.

The lock may be placed on the main power switch located outside the circuit breaker box, on the circuit breaker box itself after the applicable breaker switch has been switched to the off position, or on the switched-off circuit breaker switch using a specifically designed breaker switch lock out device.

Each lockout device will have a proper lockout tag stating the reason for the lockout, the name of the authorized employee performing the lockout, the date of the lockout and, if the

equipment is to be out of service beyond that date, the expected time period of the lockout. A sample tag is attached.

Acceptable lockout devices include color-coded keyed padlocks with a label identifying it as a lockout device and bearing the name of the authorized employee. Other devices such as multi-holed hasps (if two or more employees are to work on the locked out equipment) and circuit breaker lockouts may be used in conjunction with the padlocks. Each authorized employee will be issued an adequate number of keyed locks and will retain sole possession of the keys, except for spares in the possession of the GSI company safety officer. All lockout equipment will be substantial enough to prevent removal without the use of excessive force or unusual techniques such as bolt cutters or other metal cutting tools. In cases where placement of a lock is not possible, a tag-out label on a tie wrap may be substituted.

4.2 Verification of Deactivation/De-energizing

Once all sources of energy have been locked/tagged out, the authorized employee verify that the equipment has been de-energized by an appropriate method. For equipment on which a switch is located down-line of the lockout point, the switch will be tried prior to proceeding with the work. A volt meter will be used to verify the absence of potentially hazardous energy from electrical connections prior to disconnection.

4.3 Equipment Startup

At the completion of the job, the authorized employee is responsible for verification that the job is complete and the need for the lockout is over. At this point, the job site will be inspected to verify that restart of the equipment will not endanger personnel. All lockout devices will be removed by the authorized employee(s). The equipment may then be restarted.

4.4 Application of General Procedure

Electrical equipment currently in use by GSI is limited to pumps and related motor control equipment powered by 110 or 220 volt current. The scope of services provided by GSI does not involve maintenance or repairs to systems utilizing chemical, thermal, pneumatic, hydraulic, or radioactive energy. In addition, equipment operated by GSI meet the following criteria, specified in 29 CFR § 1910.147 (c)(4), permitting application of a single general lockout procedure and providing an exemption from development of a specific procedure for each piece of equipment:

- 1) The machine or equipment has no potential for residual or stored energy or reaccumulation of stored potentially hazardous energy after shut down;
- 2) The machine or equipment has a single energy source which can readily be identified and isolated;
- 3) The isolation and locking out of that energy source will completely deenergize and deactivate the machine or equipment;

- 4) The machine or equipment is isolated from that energy source and locked out during servicing or maintenance;
- 5) A single lockout device will achieve a lockout condition;
- 6) The lockout device is under the exclusive control of the authorized employee performing the servicing or maintenance;
- 7) The servicing or maintenance does not create other hazards for other employees;
- 8) GSI, in utilizing this exception, has had no accidents involving the unexpected activation or re-energizing of the machine or equipment during servicing or maintenance.

Accordingly, the lockout procedure described above will be followed for maintenance and service of all pumps and related equipment.

4.5 Inadvertent/Abandoned Locks

In the event that a lockout is inadvertently left on equipment or is abandoned, the lock may be removed by the GSI company safety officer or his designee. An attempt will be made to immediately notify the individual of the lock removal, and a written record made of the removal, including the location of the lockout, the individual who performed the lockout, and the individual(s) authorizing and performing the removal. The record will be maintained by the GSI company safety officer.

4.6 Training

All affected and authorized employees will be thoroughly trained in this procedure, and refresher training will be conducted annually at a minimum. Any GSI subcontractors performing work for GSI under a lockout will also be trained in the procedure, as needed. Additional training will be performed as necessary (e.g., in the event of deficiencies in implementation). Records of training will be maintained by the GSI company safety officer.

4.7 Verification of Compliance

The lockout procedure will be reviewed annually, at a minimum, to verify that the procedure is being followed and to assess the need for revision of the procedure. In addition, inspections will be conducted annually to ensure the procedure is being properly implemented.

4.8 Lockout Procedure Violations

As required by OSHA, any person violating lockout procedures will be disciplined. First violation of the lockout procedure will result in a warning and mandatory review of the lockout procedure. Repeated violation of the procedure will result in further disciplinary action, including possible dismissal.



GROUNDWATER
SERVICES, INC.

APPENDIX E

Site-Specific Health and Safety Plan Sauget Area 1 Sites Sauget and Cahokia, Illinois

GSI Health and Safety Plan

Groundwater Services, Inc.
2211 Norfolk, Suite 1000
Houston, Texas 77098
(713) 522-6300



SITE SPECIFIC PROJECT HEALTH AND SAFETY PLAN for

Project Name

Project Location

Plan Approved: _____

Date: _____

I, the undersigned, have been provided with a copy of this Site-Specific Project Health and Safety Plan. I have read the Plan, have attended a project safety orientation session conducted by Groundwater Services, Inc. (GSI), and have had the opportunity to ask questions about health and safety issues relating to this project. I understand that it is my responsibility to abide by this Plan, and that physical injury, damage and other harm to myself or others could result from my failure to do so.

[illegible]

PROJECT HEALTH AND SAFETY PLAN

1.0 SCOPE AND APPLICATION

This Project Health and Safety Plan has been prepared in accordance with 29 CFR §1910.120, and is a site-specific supplement to the GSI company Health and Safety Plan (GSI HASP), which specifies GSI's general health and safety policies and procedures. This site-specific plan is to be provided to all site workers under the direction of GSI for their review. In addition, this plan, the GSI HASP, and applicable client safety guidelines will remain on-site at all times during the project, and will be available to all project personnel upon request from the GSI Site Safety Officer (SSO) or other designated representative.

This plan specifies health and safety protocol to be followed during implementation of the project work scope by all site personnel under the direction of GSI, including employees and subcontractors. In the event of conflicting standards between this plan or the GSI HASP and client health and safety requirements, the more protective standard shall apply. All personnel are required to comply with this plan and to indicate their agreement to do so by signing the cover page.

2.0 PROJECT DESCRIPTION

2.1 General Information

Client/Site Owner	Monsanto and Solutia are the clients. The Sauget Area 1 Sites are owned by various parties, as discussed below
Project Name and General Description	Sauget Area 1 DNAPL Investigation
Project Location (Physical Address)	The sites are located near the intersection of Falling Springs R and Queeny Ave in Sauget and Cahokia, Illinois
Detailed Location Information	Sauget Area 1 Sites G, H, I, and L, which are located near the street intersections noted above
Start Date/Duration/Other Schedule Info.	Start date to be determined. Duration is likely to be approx. four to five months of field activities.

2.2 Site Description: Provide site description / attach site plan

The Sauget Area 1 Sites (Sites G, H, I, and L) were formerly used for disposal of industrial, commercial, and municipal waste materials, and are located in Sauget and Cahokia, Illinois. These CERCLA sites are roughly one mile east of the eastern bank of the Mississippi River with terrain gently sloping towards the river. Land use around the plant is primarily industrial and commercial, with some residential use. Downtown St. Louis, Missouri, is approximately 15 miles northwest of the Sauget Area 1 Sites. Site I is now a truck parking lot owned by the Cerro Copper facility. Site G is surrounded by a fence, is undeveloped, and is regularly mowed. Site H is undeveloped, is not fenced, and is regularly mowed. Site L is the parking lot for a small business (Metro Equipment). The Sauget Area 1 Sites are located on properties owned by Cerro Copper, Metro Equipment, and other parties. Current plans call for Solutia to oversee the upcoming project work at the Sauget Area 1 Sites, following resolution of property access issues.

2.3 Project Tasks: Outline major tasks, attach detailed workplan and/or operating procedures

Well Surveys: Survey all existing monitoring wells and piezometers at and near the Sauget Area 1 Sites to check for the possible presence of LNAPL and DNAPL.

Geophysical Surveys: Perform 3-D geophysical surveys of Sites G, H, I, and L in order to map the bedrock surface and identify potential topographic lows in the bedrock surface.

Soil Boring/Piezometer Installation: Install temporary piezometers using a Rotosonic drilling rig at designated locations within and outside the boundaries of Sites G, H, I, and L. Collect soil samples and conduct field screening using a PID. Examine core samples for DNAPL and retain selected soil samples for laboratory analysis. Install piezometers to investigate conditions at the bedrock surface, at depths that ranges from approx. 100-120 ft bgs.

DNAPL Recovery Tests: Conduct DNAPL recovery tests at selected wells using peristaltic pump, bailers, and/or Waterra pumping equipment.

For further information see the Work Plan and the Field Sampling Plan.

3.0 EMERGENCY RESPONSE PROCEDURES

Specify emergency reporting contact.

Call 911 for emergencies. Notify appropriate Solutia personnel of all emergencies. Additionally, all emergencies and injuries are to be reported to the GSI safety officer, Bob Lee, at (713) 522-6300.

Additional emergency response phone numbers:

Sauget Fire Department: (618) 332-6700

Cahokia Fire Department: (618) 337-5080

Sauget Police Department: (618) 332-6507 or 6697

Cahokia Police Department: (618) 337-9505

St. Claire County Sheriff: (618) 277-3500

Describe plant siren/ alarm signals, if applicable, and response

Plant siren/alarm signals may be applicable for work conducted on Cerro Copper property (i.e., at Site I). Information regarding plant sirens and alarm signals will be obtained from Cerro Copper personnel at the start of field activities and attached to the project Health and Safety Plan.

Location of emergency assembly area(s)

The Cerro Copper representative will designate the emergency assembly areas for work conducted at the Cerro Copper facility.

Describe other applicable emergency response measures to be taken

None.

Location and phone number of nearest hospital with emergency room (attach map)

A medical dispensary is located onsite at the W.G. Krummrich plant.

Nearest Hospital:

St. Mary's Hospital

129 N 8th St, Sauget, IL 62201

Phone: (618) 274-1900

(See attached map)

4.0 PROJECT ORGANIZATION, PERSONNEL, & TRAINING REQUIREMENTS

4.1 Key Personnel

Position	Name	Phone (Pager/Cell Phone)
GSI Project Team Leader (PTL)	James A. Kearley	(713) 522-6300
GSI Site Manager	James A. Kearley	
GSI Site-Safety Officer (SSO)	Robert S. Lee	(713) 522-6300
Solutia Project Manager	Kimberly Perry	(314) 674-3402 (phone)
Solutia H&S Representative	Kimberly Perry	(314) 294-3402 (pager)
Solutia CMR	Robert J. Hiller	(618)-482-6362

4.2 Training Requirements – Check all that apply and list any additional

x	OSHA 40-hr HAZWOPER
x	Site-Specific (video)
	Unit specific

4.3 Requirements for Respirator Use

Will respirator use potentially be required? ☒ Yes ☐ No

If yes, GSI Respiratory Protection Plan, found in Section 6.0 of the GSI HASP, is applicable. Affected personnel must have physician's written opinion certifying fitness to use respirator based on pulmonary function test and other considerations, be trained in proper respirator use, and have quantitative fit test. This documentation must be provided to the Solutia CMR.

4.4 Personnel Documents

List documentation of training or medical fitness project personnel will be required to provide.

Medical fitness records, including respirator use certification, will be provided to the Solutia CMR for all workers who have the potential to don respirators. In addition, negative drug test results (for the current year) will be available for all workers entering the Cerro Copper property (i.e., Site I).

5.0 POTENTIAL HAZARDS & HAZARD CONTROL MEASURES

5.1 General Site Access Control

Specify site control measures as necessary to prevent unauthorized persons from entering work area.

Work zone security will be monitored by the GSI site manager. Necessary controls will be used to prevent unauthorized access to work areas and may include barricades, tape, and signs.

5.2 Project Personnel Access Control

Specify sign-in and sign out procedures for project personnel, and means of notifying site manager if unable to be on-site.

At the start of each workday, all workers are to check in with the GSI site manager. sign-in and sign-out procedures For work conducted at the Cerro Copper property,

5.3 Underground Utilities Clearance

Specify procedures for obtaining clearance of locations for drilling, excavation, or other subsurface penetrations

Specify date of call, response and case or serial no. For clearance of site-owned utilities, provide contact and response information.

For work conducted at the Cerro Copper property (i.e., Site I), utility clearance will be coordinated with Cerro Copper representatives using the plant's excavation permit procedure. No subsurface work is to be done on that property prior to receiving that permit from the Cerro Copper representative. For all drilling locations, including locations at the Cerro Copper facility, clearance is required using the Illinois JULIE system (1-800-892-0123 or www.illinois1call.com). The call must be placed 48 hours in advance of any digging or drilling, and the digging or drilling must be completed within 14 days of the call.

5.4 General Work Hazards and Avoidance

General work hazards include slip, trip, and fall hazards, head or foot injuries from falling or dropped objects, strains from over-exertion or incorrect lifting, electrical shocks, etc. These hazards can be controlled by good housekeeping measures and safe work practices, as outlined below. See also GSI HASP.

Housekeeping Measures:

- Excess brush or high vegetation should be cleared from the work area to the extent practical prior to start of the job.
- The job site must be kept clean and free of trash and debris. Trash will be placed in bags or other suitable containers when generated. Disposable PPE must be disposed in designated containers upon removal.
- Materials such as lumber, well screen and riser pipe, filter pack sand, cement, etc. will be neatly stored in a designated area.
- Tools and equipment must be returned to the tool box or designated area when no longer in use.

General Safe Work Practices:

- Use buddy system.
- Stay alert at all time to activities in your surroundings. Watch for on-coming vehicles, other workers, and overhead hazards.
- Work at a deliberate pace; do not rush a job.
- Avoid heavy lifting and lift with knees bent.
- Use tools only for their intended use, and make sure tools are in good condition. Inspect power tool and extension cords prior to use.
- Maintain safe distance between drillrig mast or other overhead equipment and overhead lines.
- Avoid unauthorized entry to restricted areas including confined space areas.
- Do not operate plant process equipment; do not open or close valves
- Proper PPE (specified below) must be worn at all times. PPE must be inspected regularly and properly maintained.
- Remove gloves and wash hands before handling food or tobacco products.

5.4 Fire and Explosion Hazard Mitigation

- All drilling or excavation locations must be properly cleared for the presence of underground utilities prior to drilling or digging. (Utility clearance procedures are specified above).
- Gasoline and other fuels must be stored in steel safety cans with mesh flame arresters and spring-mounted relief vent mechanisms. Flammable and combustible materials including paints and solvents must be properly stored away from sources of ignition.
- Fire extinguishers must be present on all vehicles and drilling and excavation equipment, and in all areas where spark producing equipment is in use.

Other Measures (check as applicable)

- ☐ No smoking permitted
- ☒ Smoking permitted only in designated areas
- ☒ Matches and lighters not permitted onsite
- ☒ Hot-work permits must be obtained for spark-producing equipment in designated areas.
- ☒ Other Additional measures where required by Cerro Copper for work at Site I.

5.5 Heat-Related Disorders

The major varieties of heat-related disorders, their related symptoms and appropriate treatment are listed below in order of increasing severity.

Condition & Related Symptoms	Heat Stress	Heat Exhaustion or Heat Syncope	Heat Stroke
Cramping	May be present	May be present	Absent
Mental State	Faint, dizzy, fatigue	May be disoriented	Stupor or coma
Skin & Complexion	Cool, moist, flush; rash may be present.	Cool, pale, moist	Red, hot, dry
Temperature	Normal	Normal to low	Very high (>105° F)
Pulse	Rapid (>110 beat /min)	Rapid, weak	Rapid, bounding
Blood Pressure	May be low	May be low	May be high in early stages
Treatment	Give water & electrolytes, loosen or remove clothing, move to shade	Give water & electrolytes, loosen or remove clothing, move to shade	Provide rapid cooling by immersion; cover in wet cloth and transport to emergency room

Prevention Measures: All heat disorders are caused by loss of fluids and the body's inability to cool itself. Heat stress can be prevented by the following measures:

- Pre-hydrate before going into the field: water or water-electrolyte drinks are preferable to caffeinated beverages or soft drinks. Refrain from alcohol the night before field work.
- In the field drink frequently. Numerous small drinks at a tepid temperature are better than rapid, large volume intakes of iced drinks.
- Rest at least a few minutes every hour or two.
- Observe co-workers for signs of heat stress.

5.6 Heavy Equipment Operations

Drilling and other equipment must be in good condition. Particular attention should be paid to the condition of cables and hoisting equipment. The equipment must be equipped with a back-up beeper. Barricades or caution tape should be used as needed to exclude unauthorized personnel from the work area.

During drilling, the drillrig should be positioned to allow for adequate work room and the area should be kept free of trip and slip hazards. Care must be taken to avoid the catching of loose clothing in moving parts, and to keep hands free of pinch points. Proper PPE including hard hat, safety glasses, gloves, hearing protection, and safety shoes must be worn.

5.7 Confined Space and Excavation Safety

All personnel must obey all posted restrictions on entry to confined spaces. Excavations deeper than 4 ft should not be entered for any purpose unless 1) the excavation walls are properly shored or are sloped at a 1:1 slope, or less steep, and there is no danger of collapse or engulfment; 2) a suitable means of egress such as ramp, stairs or ladder is located so as to require no more than 25 ft of lateral travel to reach it; and 3) testing demonstrates a hazardous atmosphere is not present.

5.8 Potential Chemical Exposure Hazards

Summarize primary constituents of concern, relevant exposure levels, and the maximum expected concentrations in soil and/or groundwater, to the extent known. Provide Material Safety Data Sheets (MSDS) in Attachment A.

CONSTITUENTS OF CONCERN (COCs)	Exposure Limits ¹			Max. Expected Concentration or Free-Phase (FP)		Health Hazard Target Organ Route of Entry ²
	PEL/ TLV (ppm)	STEL (ppm)	IDLH (ppm)	Soil mg/kg	Water mg/L	
Chemical Name CAS No.						Ca = Carcinogen, Abs = skin absorption Con = skin or eye contact Inh = Inhalation. Ing = ingestion
Benzene	1	5	500	FP	FP	Ca, Abs, Con, Inh
Chlorobenzene	75	NPV	1000	FP	FP	Inh, Ing, Con
1,2-Dichlorobenzene	50	NPV	200	FP	FP	Inh, Abs, Ing, Con
1,3-Dichlorobenzene	NPV	NPV	NPV	FP	FP	
1,4-Dichlorobenzene	75	NPV	150	FP	FP	Ca, Inh, Abs, Ing, Con
Phenols	5	15	250	-	25	Inh, Abs, Ing, Con
Chloroanilines	NPV	NPV	NPV	-	25	

1 Unless otherwise noted, Permissible Exposure Limits (PEL) and Threshold Limit Values (TLVs) are permissible time-weighted average exposure limits (ppm in air) which must not be exceeded for an 8-hour work-day/40-hour work week. Short-Term Exposure Limits (STELs) must not be exceeded over a 15-minute period. IDLH –Immediately Dangerous to Life or Health must not be exceeded at any time. NPV = No published value. ND = Not determined

2 See also NIOSH Pocket Guide to Chemical Hazards.

To minimize potential chemical exposure, the following measures will be taken:

- Workers should remain upwind of contaminated materials to the extent practical.
- PPE specified below will be worn prevent skin or eye contact with constituents.
- Air quality monitoring will be conducted and respiratory protective equipment used as needed, as described below.
- Eating, drinking, smoking, gum chewing and oral tobacco use are not permitted in areas where chemical exposure could occur.
- Workers must remove gloves in the work area and drink from a water source outside the immediate work zone.
- PPE must be removed and hands thoroughly washed prior to breaking for meals.

5.9 Other Potential Hazards

List other potential hazards associated with the site and/or specific tasks and describe hazard mitigation methods.

Fans will be on-site and available for use as needed during the field program as an engineering control for minimizing exposure to organic vapors.

6.0 AIR QUALITY MONITORING

Air Monitoring Instrument

- ☒ PID with span-gas calibration
- ☐ OVA 128 Calibrated to methane standard
- ☒ Drager Tube (specify compound & use) benzene, phenol
- ☒ Personnel Badges (specify compound & use) benzene
- ☒ Lower Explosive Level (LEL) _____
- ☐ Other (Specify) _____

Monitoring Frequency and Location

Identify tasks during which air monitoring is to be performed

Air monitoring will be performed during: i) well surveys for measuring DNAPL thickness; ii) drilling, soil sampling, and piezometer installation; and iii) DNAPL recovery tests.

Specify where will monitoring be performed (e.g., Worker's breathing zone, site perimeter, contaminant source area, or other area) and Monitoring Frequency (e.g., Continuous, Periodic {hourly, etc.}, on detection of noticeable odor)

Monitoring will be conducted using the PID to measure organic vapor concentrations. Air monitoring will also be performed using an LEL, on an as-needed basis. Draeger tubes will be used to test for benzene and phenol if total organic vapors measured in the workers breathing zone by the PID exceed 5 ppm for sustained 1-minute intervals. In addition, to measure time-weighted average benzene exposure over an eight hour day, two workers will wear benzene badges on the first day of each of the major project tasks (i.e., well surveys, drilling, and DNAPL recovery tests).

Well surveys: Air quality will be monitored in the workers breathing zone at the top of each well casing prior to beginning work at that well. Additional measurements will be conducted at each location if needed based on detection of noticeable odor.

Drilling, soil sampling and piezometer installation: Continuous air monitoring will be performed in the breathing zone of the workers who operate the drilling equipment and in the breathing zone of personnel who examine and handle soil cores. **Drilling through fill materials will be conducted in Level B PPE.**

DNAPL recovery tests: Continuous air monitoring will be performed in the breathing zone of the workers who perform the recovery tests.

7.0 PERSONAL PROTECTIVE EQUIPMENT (PPE)

7.1 Level D PPE

A minimum of Level D PPE is required for all site personnel at all times, upgraded as necessary depending on task and conditions. Basic Level D PPE shall include the following elements: **1) Hard Hat** (w/ mono goggles); **2) Safety Glasses** (w/side shields); **3) Safety Shoes** (w/steel toes); **4) Body Covering** (long pants, shirt w/ long sleeves, collar). Basic Level D equipment will be supplemented as follows:

SUPPLEMENTAL LEVEL D PPE

Item	When/Where to be Used
Flame Retardant Clothing (FRC)	
<input checked="" type="checkbox"/> Hearing Protection	Around noisy plant areas or drilling operations
<input checked="" type="checkbox"/> Work gloves	While handling equipment.
Latex or vinyl surgical gloves	
<input checked="" type="checkbox"/> Neoprene or Nitrile gloves	While handling soil NAPL samples.
<input checked="" type="checkbox"/> Tyvek Coveralls	As necessary while handling soil.
Polycoat Tyvek Coveralls	
Chemical-resistant boots	
<input checked="" type="checkbox"/> Face Shield	During DNAPL recovery tests

7.2 Level C PPE

Specify action level conditions for Level C PPE (use of Air-Purifying Respirator)

Upgrade to Level C will occur if OVA readings of > 5 ppm are sustained for more than one minute and if i) Draeger tube results for benzene exceed 1 ppm, or ii) Draeger tube results for phenol exceed 5 ppm. Otherwise, upgrade to Level C will occur if OVA readings of >10 ppm are sustained for more than one minute. Upgrade to Level C can occur at the discretion of the GSI site safety officer if nuisance odors are present.

Specify equipment and limitations

_____ Half-face Respirator up to _____ ppm, TOV or _____ ppm (compound) by Draeger
___X___ Full Face Respirator up to _____ 30 ppm, TOV or _____ 10 ppm benzene by Draeger

Specify Cartridge Type Organic Vapors

Specify action level conditions for Level B (Supplied Air) if applicable, or suspension of work.

If OVA readings of >20 ppm are sustained for more than one minute, then a Draeger tube will be used to measure benzene. If the benzene concentration exceeds 10 ppm, then work will be stopped for further evaluation and possible upgrade to Level B PPE. If the Draeger tube results indicate that the benzene concentration is less than 10 ppm, then Level C work can continue. Level C work will be suspended in OVA readings of >30 ppm are sustained for more than one minute, or if benzene concentrations in ambient air reach 20 ppm.

7.3 Level B PPE

Specify Level B Equipment (pressure demand, continuous flow, etc.).

The drilling subcontractor will provide continuous flow supplied air and all related equipment such as hoses and masks for possible use during soil sampling, well installation, and well development.

Specify Level B Procedures (personnel, air supply monitoring, etc.).

The drilling contractor will provide an experienced Level B PPE program manager to supervise the usage of supplied air and PPE to conduct air monitoring during soil sampling, drilling, and well development activities.

Specify conditions For Project Shut-down.

8.0 DECONTAMINATION PROTOCOL

Specify procedures for personnel decontamination and management of disposable PPE.

Wash hands before eating, drinking, or smoking, and before leaving the site. PPE are to be disposed as directed by the Solutia CMR.

Specify procedures for response to non-emergency chemical release.

Notify Solutia and GSI Project Team Leader. Where appropriate, use sorbent material to contain spilled liquids.

9.0 ADDITIONAL INFORMATION

Provide any additional information, procedures, or instructions as needed.



GROUNDWATER
SERVICES, INC.

SITE SAFETY MEETING

Project/Location: _____

GSI Job No. _____

Site Safety Officer: _____

Page 1 of 1

Date: _____

Meeting Conducted By: _____

Meeting Attended By:

<u>Name</u>	<u>Company</u>	<u>Signature</u>
-------------	----------------	------------------

1) _____

2) _____

3) _____

4) _____

5) _____

6) _____

_____ Additional Personnel (See Next Page)

Tasks to be Performed

Potential Hazards and Hazard Avoidance Measures

Mechanical Hazards: _____

Heat stress: _____

Chemical exposure: _____

Biological hazards: _____

Other: _____



GROUNDWATER
SERVICES, INC.

DAILY SITE SAFETY RECORD

Project/Location: _____

GSI Job No. _____

Site Safety Officer: _____

Page 1 of _____

Date: _____

Field Personnel

Name	Company	Time Onsite-Offsite	Time Onsite-Offsite
1) _____	_____	_____	_____
2) _____	_____	_____	_____
3) _____	_____	_____	_____
4) _____	_____	_____	_____
5) _____	_____	_____	_____
6) _____	_____	_____	_____

_____ Additional Personnel (Attach additional sheets as needed.)

Work Item/Personal Protective Equipment Level

Task: _____

Personnel: _____ PPE: _____

Task: _____

Personnel: _____ PPE: _____

Air Quality Monitoring: _____ See Record (next page) Not Required__

Safety Awareness Issues Discussed: _____

ACCIDENTS/INJURIES/INCIDENTS

(Description of Incident, Actions Taken. Attach additional sheets as needed)



GSI Job No. _____
Page 2 of _____
Date _____

_____ Foxboro OVA 128
Calibration Check:
(95 ppm Methane Gas)

Other (Specify) _____
 10 X Scale Reading (ppm) _____
 100 X Scale Reading (ppm) _____

[illegible]

* Reading above background, sustained for 1 minute period.

Action Level ppm Action Level Exceeded?

Action Taken _____

Remarks _____



GROUNDWATER
SERVICES, INC.

APPENDIX F

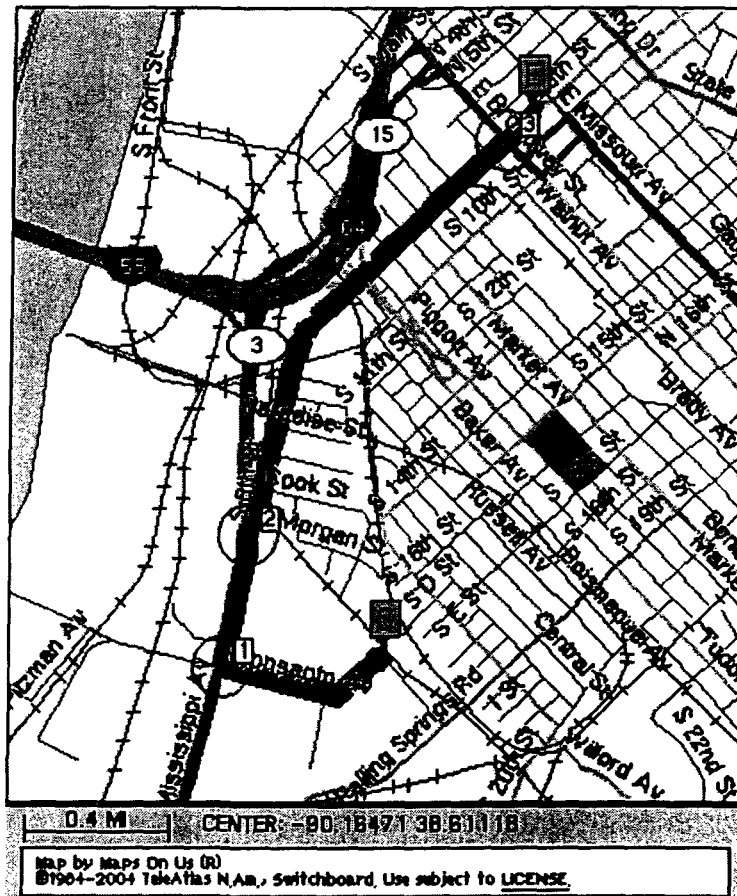
Attachments to Site-Specific Health and Safety Plan

Map to St. Mary's Hospital, Sauget, Illinois

GSI Health and Safety Plan

Groundwater Services, Inc.
2211 Norfolk, Suite 1000
Houston, Texas 77098
(713) 522-6300

Map and Driving Directions to St. Mary's Hospital
Sauget, Illinois



Driving Directions:

Exit the Solutia W.G. Krummrich Plant and proceed west on Monsanto Avenue to Illinois State Route 3 (IL 3 N). Drive north on IL 3 N. Take the 170 East/I-55 North exit toward Chicago/Indianapolis. Take the 4th St Exit toward Business District/East St. Louis. Merge onto south 4th Street, turn right onto east Broadway/IL 15. Turn left onto north 8th Street. St. Mary's Hospital is located at 129 North 8th Street. The distance from the plant to the hospital is approximately three miles. The estimated driving time is seven minutes.